

National Scientific Workshop

Micro and Smart Grids

**October 6th
2017**

Cité Descartes

Bâtiment Bienvenue
14-20 Bd Isaac Newton
77420 Champs-sur-Marne

Poster Session
Oral Presentations
Discussion



**Invited
Speakers**

- **Josep M. GUERRERO**
Aalborg University, DENMARK
- **Nikolaos HATZIARGYRIOU**
University of Athens, GREECE
- **Romeo ORTEGA**
Paris-Saclay University, FRANCE
- **Carlos BORDONS**
University of Sevilla, SPAIN

Programme committee

Technical Program Co-Chairs

- Manuela SECHILARIU, Université de Technologie de Compiègne, France
GT Micro-réseaux (GRD SEEDS)
- Gilney DAMM, Université Paris-Saclay, France
GT RSEI (GDR MACS)
- Lilia GALAI-DOL, ITE Efficacy, France

Publicity and Communication

Olivia CAILLOU, ITE Efficacy, France

Local Arrangement

- Lilia GALAI-DOL, ITE Efficacy, France
- Florence DUPONT-TROPAMER, ITE Efficacy, France
- Olivia CAILLOU, ITE Efficacy, France
- Josiane GILLES, Université de Technologie de Compiègne, France
- Fabrice LOCMONT, Université de Technologie de Compiègne, France
GT Micro-réseaux (GRD SEEDS)

Sponsor



The National Center for Scientific Research is a public research organization (a public scientific and technological institution under the auspices of the Ministry of National Education, Higher Education and Research). It produces knowledge and puts this knowledge at the service of society.

Co-organizers



The research group SEEDS (Electrical Energy Systems in their Societal Dimension) federates the laboratories and academic teams of electrical engineering (CNRS, the Ministry of Research, and other research organizations); it also maintains close links with the scientific communities concerned with the problems of generation, distribution, transformation and use of electrical energy and with the materials, methods and technologies that contribute to the realization of efficient, safe and environmentally friendly electrical devices and systems.



The MACS GdR is a structure of scientific animation of the Automated - Productive community, structured according to different thematic axes. Its role is to help the structuring of research and joint synergies by bringing together all the forces in the disciplines covered by the GdR. It must therefore play a leading role in amplifying current research activities, in facilitating the emergence of new research themes that are particularly promising, and in defending the specificities and scientific issues of our disciplines with funding institutions and organizations. For more details, you can consult the presentation of the 2014-2017 project or prospects and archives.



Efficacity is an R&D institute dedicated to energy transition in urban territories. Since its launching in 2014, it brings together the skills of over 100 researchers from industry and public research on a single site, to foster close collaboration between all the stakeholders. Efficacity develops innovative and scientifically robust solutions allowing urban actors to be more efficient at every stage of a sustainable urban development project.



To the purpose to adress the technical constraints of interfacing renewable sources with the public electricity network, AC or DC micro-smart grid composed of a multi-source system and related controller/supervisor represent an integrated solution. Whether they are integrated into the distribution system or the transmission network, which can be AC or DC, HV or LV, high power or small power, the micro-smart grid or the componing clusters require a hierarchical control approach. It will be composed by a systemic approach studying the interactions among the subsystems, with to each operation mode adapted control laws, and a specific approach related to the intermittent aspects of the system.

The National Scientific Workshop on micro-smart grid is organized by the GT Micro-réseaux (GDR SEEDS) and the GT RSEI (GDR MACS) in collaboration with the ITE Efficacy. The event will take place in Marne-la-Vallée on October 6th and will allow researchers, PhD students and industrial partners to present their work and to exchange on the micro-smart grid' theme. This will aim to introduce both theoretical and pratical micro-smart grid developments, offering information on their control and the possible industrial applications. Possible interesting subjects and related applications are :

- Modeling, control and management of micro-smart grid;
- Control for AC and DC micro-smart grid;
- Energy and power quality for micro-smart grid;
- Renewable energy integration and multi-energy systems;
- Static converters for micro-smart grid (topologies, efficiency, performance, etc.);
- Energy storage systems for micro-smart grid;
- Energy management for micro-smart grid (optimal planning, load shedding, real-time optimization, uncertainties evaluation, etc.);
- Test-beds, case-studies and pilot projects.

Invited Speakers

Josep M. Guerrero, Professor

• Aalborg University, Faculty of Engineering and Science, Department of Energy Technology
• Director of Microgrids Laboratory
(<http://www.et.aau.dk/research-programmes/microgrids/>)

Nikolaos Hatziaargyriou, Professor

• National Technical University of Athens, School of Electrical and Computer Engineering
• Director of SmartRUE Laboratory
(<http://www.smarttrue.gr/>)

Romeo Ortega, Professor

• Laboratoire des Signaux et Systèmes, Centrale Supélec, Paris-Saclay University
• Research Director, L2S Laboratory
(<http://www.l2s.centralesupelec.fr/en>)

Carlos Bordons, Professor

• Professor, University of Sevilla, Spain
• Member of the European Union Control Association Council

Programme	
8:00	Opening reception
8:30	Welcome and introductions by GT Micro-réseaux, GT RSEI and Efficacy <i>Amphitheatre Bienvenüe</i>
9:30	Plenary session : J. Guerrero & N. Hatziargyriou <i>Amphitheatre Bienvenüe</i>
10:30	Coffee break
11:00	Plenary session : R. Ortega & C. Bordons <i>Amphitheatre Bienvenüe</i>
12:00	Poster Session (poster GT Micro-réseaux & posters Efficacy) <i>Room B 015-019</i>
13:00	Lunch
14:00	<div> <div> Session «GT Micro-réseaux» <i>Amphitheatre Bienvenüe</i> </div> <div> Session «GT RSEI - Réseaux et Systèmes Électriques Intelligents» <i>Amphitheatre A 017</i> </div> </div>
16:00	Coffee break
16:30	Discussion & conclusion <i>Amphitheatre Bienvenüe</i>
17:30	

Invited Speakers



Josep M. Guerrero, Fellow, IEEE

Professor J. M. Guerrero is with the Department of Energy Technology, Aalborg University, 9220 Aalborg East, Denmark
(Tel: +45 2037 8262; Fax: +45 9815 1411; e-mail: joz@et.aau.dk).

New Research Challenges in Industrial and Residential Microgrids

Abstract: A microgrid can be defined as a part of the grid with elements like distributed energy sources, power electronics converters, energy storage devices and controllable local loads that can operate autonomously in islanded mode but also interacting with the main power network in a controlled, coordinated way. Following the introduction of distributed control of these elements, cooperative control and hierarchical control schemes for coordination of power electronics converters in order to control the power flow and to enhance the power quality will be elaborated. Different technologies are combined together, such as power converters, control, communications, optimization, and so on. This way, energy can be generated and stored near to the consumption points, improving stability and reducing losses produced by large power lines. In distributed energy systems like microgrids, multi-agent systems technologies will be presented, including distributed control. Previous experiences in the Danish electrical system like the Cell Controller project used these technologies to balance dispersed energy generation and consumption. The focus of this presentation will be on the analysis, modelling and control design of power electronics-based microgrids, as well as power electronics control and communications. Further, the interconnection of microgrid clusters will be emphasized as an important step towards utilization of the smart grid concept. Examples of real sites including conventional islanded systems installed in islands and rural remote areas will be shown. Finally, low-voltage distribution systems and DC microgrids for residential applications and homes will be introduced. New worldwide projects to develop technologies for low voltage DC distribution systems will be shown, such as DC shipboard systems, DC datacenters, and DC electric vehicles charging stations.

Biography: Josep M. Guerrero (S'01-M'04-SM'08-FM'15) received the B.S. degree in telecommunications engineering, the M.S. degree in electronics engineering, and the Ph.D. degree in power electronics from the Technical University of Catalonia, Barcelona, in 1997, 2000 and 2003, respectively. Since 2011, he has been a Full Professor with the Department of Energy Technology, Aalborg University, Denmark, where he is responsible for the Microgrid Research Program (www.microgrids.et.aau.dk). From 2012 he is a guest Professor at the Chinese Academy of Science and the Nanjing University of Aeronautics and Astronautics; from 2014 he is chair Professor in Shandong University; from 2015 he is a distinguished guest Professor in Hunan University; and from 2016 he is a visiting professor fellow at Aston University, UK, and a guest Professor at the Nanjing University of Posts and Telecommunications.



Nikolaos D. Hatziargyriou, Fellow, IEEE

Professor Nikolaos D. Hatziargyriou is with the Power Division of the Electrical and Computer Engineering School of the National Technical University of Athens, 9, Iroon Polytechniou St, Athens, Greece (Tel: +30 (210) 7723836; Fax: +30 (210) 7723836; e-mail: nh@power.ece.ntua.gr).

Intelligent Control of Microgrids

Abstract: The main characteristics of Microgrids as building blocks of the future power systems will be introduced and their benefits and technical and commercial challenges will be presented. Decentralized control of Distributed Generators and Flexible Loads in Microgrids will be discussed and the key features of intelligent Multi Agent Systems (MAS) will be briefly described. Results from several EU pilot applications will be presented. In particular, the application of MAS on an isolated settlement of 12 houses powered solely by solar power on the Greek island of Kythnos will be presented. In this application intelligent load controllers with Embedded processors have been used to host the agents, in order to achieve a more efficient use of energy. New techniques have been tested such as: negotiation algorithms, wireless communication, CIM based ontology etc. Further pilot applications will be described highlighting the applicability of Decentralized Intelligent Control approaches.

Biography: Professor Nikos D. Hatziargyriou is since April 2015 Chairman and CEO of the Hellenic Distribution Network Operator. Since 1984 he is a faculty member at the Power Division of the Electrical and Computer Engineering School of the National Technical University of Athens. From February 2007 to September 2012, he was Deputy CEO of the Public Power Corporation (PPC) of Greece, responsible for Transmission and Distribution, island DNO and the Center of Testing, Research and Prototyping. He is Fellow Member of IEEE, past Chair of the Power System Dynamic Performance Committee, Honorary member of CIGRE and past Chair of CIGRE SC C6 "Distribution Systems and Distributed Generation". He is co-chair of the EU Technology and Innovation Platform on Smart Networks for Energy Transition. He has been one of the pioneers of the concepts of Microgrids and Smart Grids in Europe. He has developed simulation tools for the dynamic analysis of islanded microgrids and advanced centralized and decentralized control techniques based on intelligent agent technologies providing DER "plug and play" capabilities with limited communication. He has proved the feasibility of these concepts in laboratory environment and he has coordinated their installation in actual installations. He has advanced the state of the art in the areas of Distributed and Renewable Energy Sources through his involvement in numerous projects performed for electric utilities and manufacturers in Europe, for both fundamental research and practical applications. He is Editor in Chief of the IEEE Transactions on Power Systems and member of the Editorial Board of IEEE Transactions on Sustainable Development and the IEEE Power and Energy magazine. He is author of the book "Microgrids: Architectures and Control" and of more than 200 journal publications and 500 conference proceedings papers. He is included in the 2016 Thomson Reuters' list of the top 1% most cited researchers.

Plenary session

Invited Speakers



Romeo Ortega

Professor Romeo Ortega is with the Laboratoire des Signaux et Systèmes, Centrale Supélec, Paris-Saclay University, France

Research activities on power systems and power electronics

Abstract: In this brief talk we describe the activities of our group on these areas for the period 2013-2017. The reported results include:

- modular modeling of power systems
- analysis and control of transient stability phenomena
- modeling and PI control of HVDC systems
- modeling and droop control of microgrids
- identification and control of alternative energy generation systems (wind and photovoltaic arrays)
- analysis and control of power converters: PI control and constant power loads

Biography: Romeo Ortega was born in Mexico. He obtained his BSc in Electrical and Mechanical Engineering from the National University of Mexico, Master of Engineering from Polytechnical Institute of Leningrad, USSR, and the Docteur D'Etat from the Politechnical Institute of Grenoble, France in 1974, 1978 and 1984, respectively. He then joined the National University of Mexico, where he worked until 1989. He was a Visiting Professor at the University of Illinois in 1987-88 and at the McGill University in 1991-1992, and a Fellow of the Japan Society for Promotion of Science in 1990-1991. He has been a member of the French National Researcher Council (CNRS) since June 1992. Currently he is in the Laboratoire de Signaux et Systemes (SUPELEC) in Paris. His research interests are in the fields of nonlinear and adaptive control, with special emphasis on applications. Dr Ortega has published three books and more than 290 scientific papers in international journals, with an h-index of 74. He has supervised more than 30 PhD thesis. He is a Fellow Member of the IEEE since 1999 and of IFAC since 2016. He has served as chairman in several IFAC and IEEE committees and participated in various editorial boards of international journals.



Carlos Bordons

Professor Carlos Bordons,
University of Seville, Spain

Control of microgrids integrating renewable energy and hybrid storage

Abstract: This talk will present an overview of the challenges related to the control of microgrids which include renewable sources (mainly solar and wind) and hybrid storage (both electricity and hydrogen). It will be focused on the control methodologies in the framework of Model Predictive Control (MPC). Energy management systems will be designed trying to fulfil different control objectives, related to economic profit, power balance, durability of the microgrid components and environmental issues. The intrinsic uncertainty associated to renewable generation and demand can be considered using Stochastic MPC. The optimal operation of networks of microgrids is also addressed, using a solution based on Distributed MPC. Real experiments on a laboratory-scale DC microgrid as well as simulated results will be used to illustrate the concepts.

Biography: Carlos Bordons received the Ph.D. degree in Electrical Engineering in 1994. He joined the Escuela Superior de Ingenieros of Seville (Spain) as an Assistant Professor and he is currently Full Professor of Systems Engineering and Automatic Control there. He has worked in different projects in collaboration with industry in fields such as control of power management in hybrid vehicles, control of microgrids including renewable sources, simulation and optimization of oil pipeline networks, automation of copper furnaces or modelling and control of fuel cells systems. His current research interests include advanced process control, especially model predictive control and its application to hybrid vehicles. His recent work is focused on power management in hybrid systems including fuel cells as power sources, as is the case of hybrid vehicles and microgrids. He is co-author of the books *Model Predictive Control in the Process Industry* and *Model Predictive Control* (1st and 2nd edition) published by Springer-Verlag, London. He holds three related patents and is a senior member of the Institute of Electrical and Electronic Engineers. He is currently Associate Editor of the journals *IEEE Trans on Industrial Electronics*, *Control Engineering Practice* and *Revista Iberoamericana de Automatica e Informatica Industrial*. He was EUCA (European Union Control Association) Council Member since 2007 to 2015. Since 2008 to 2012 he was the Managing Director of AICIA, which is the main Research and Technology Organization in Andalusia (Southern Spain). He is founder of the start-up IDENER, a spin-off company oriented to applications of Advanced Control and Optimization techniques. He is currently the Head of the Systems Engineering and Automation Department at the University of Seville.

GT Micro-réseaux, SEEDS

SCALING OF WIND ENERGY CONVERSION SYSTEM

A. Varais, X. Roboam, F. Lacressonnière, J.M. Cabello, E. Bru, J. Pulido

Abstract - This paper presents a scaling methodology based on dimensional analysis and applicable to systems' mathematical models. The main goal of this research is to propose time-compressed HIL experiments together with reduced power, while keeping similarity with respect to the dynamics of the original system. The scaling process is presented using a simple wind turbine model. This reduced model is validated through a simulation in which the wind conversion system is connected to a scaled electrochemical battery.

Keywords – Wind System, Similarity, Scaled Systems, Time Acceleration, HIL.

I-V CURVE SCANNING IN PARALLEL ARCHITECTURE BASED ON DC SOLAR OPTIMISERS

JP. Sawicki, F. Saint-Eve, P. Petit, F. Mauffay, M. Aillerie

Abstract – Use of optimisers connected to individual photovoltaic (PV) modules allows new capabilities like survey of power for each module. In this paper we show that it is possible to extract I-V curves without stopping electricity supply in the case of parallel solar optimisers. Analysis of such data would make easier PV generator diagnosis, particularly in partial shadowing.

Keywords – DC micro-grid, Photovoltaic modules, Solar optimisers, I-V curves, Shadowing.

OPTIMAL ENERGY MANAGEMENT OF MULTISOURCE PRODUCTION SYSTEM FOR SELFCONSUMPTION IN ISOLATED AREAS

R. Saidi, M. Machmoum, J. C. Olivier, E. Cheveau

Abstract – In this paper, a new energy management strategy (EMS) is designed for a hybrid power system composed of photovoltaic panels (PV) and Proton Exchange Membrane Fuel Cell (PEMFC) as energy sources, a battery and ultracapacitor (UC) as energy storage systems (ESS). The designed EMS is based on residential power and solar power forecasting. The main aim of the proposed strategy is to reduce the total operating cost of the system while satisfying the constraints required by the ESS.

Keywords – Hybrid power system; energy management strategy; operating cost.

DECENTRALIZED MICROGRID COORDINATION USING MULTI-AGENT SYSTEMS

Jin Wei, Robin Roche, Abder Koukam, Fabrice Lauri

Abstract - Microgrid (MG) networks are expected to help increase grid flexibility and the integration of renewable generation. To improve network cooperation performance, this paper proposes a novel distributed control strategy to manage energy flows using a multiagent system. Power dispatching is achieved through flexible electricity markets to maximize MG profit. A distributed power flow calculation algorithm is proposed to guarantee that the power flow in the network is within line capacity. Simulation shows that the control strategy manages to ensure MG power balance while maximizing profit. Additionally, the power flow is within line capacity to guarantee system security.

Keywords – micro grid, multi-agent system, power management, distributed system, optimization

MICROGRID AND ELECTROMOBILITY IN URBAN AREAS

M. Sechilariu, F. Locment (AVENUES)

Abstract - Greenhouse gas emissions, produced by transport sector, have spurred the rapid growth of the electromobility. Nevertheless, this new form of mobility requires installing recharging infrastructures for electric vehicles (EVs) in urban areas, both self-service and not. This paper aims at: a) presenting an innovative energy system, and b) at highlighting the issues for its implementation in an urban area. The proposed energy system consists of three components: an intelligent charging station for electric vehicles (iCS_EVs), a heterogeneous fleet of electric vehicles (EVs), and a building with a connection to the iCS_EVs. This paper focuses on requirements and feasibility of iCS_EVs best fitting urban areas. This energy system is embedded into the urban space in which is installed through multiple physical and logical interactions. The iCS_EVs is based on a smart microgrid optimizing the power flows in accordance with the requirements of the public power grid. This microgrid contains photovoltaic sources and takes into account the following strategies: vehicle to grid, vehicle to building, and iCS_EVs to building (energy generated by the iCS_EVs and not used by the EVs directly feeds the building). Therefore, the innovative energy system offers new services that can be synergistic with the urban electromobility.

Keywords - *electromobility; microgrid; renewable energy; electric vehicles; urban planning.*

POWER LINE COMMUNICATION FOR BATTERY MANAGEMENT SYSTEM IN AN AUTONOMOUS PHOTOVOLTAIC LED LIGHTING SYSTEM

T. K. Tran, Y. Ould-boukhite, H. Yahoui, N. Siauve, D. Genon-Catalot

Abstract – In an autonomous photovoltaic system, energy management is highly important. The batteries is used in the system to store the energy. It needs to be equipped with a battery management system (BMS) for power flow control, lifetime improvement and safety issues. In order to avoid the use of additional wire for communicating which will cause cost increasing, the power line communication is employed to manage power in the system.

Keywords – *Power line communication, Battery management system, Photovoltaic, LED lighting system.*

PREDICTIVE CURRENT CONTROL IN GRID CONNECTED PHOTOVOLTAIC SYSTEM

Boualem Boukezata, Jean-Paul Gaubert, Abdelmadjid Chaoui

Abstract - This paper proposes a predictive current control in multifunctional gridconnected photovoltaic system. To ensure the multifunctional feature, the proposed control uses the system discrete-time model to predict the future value of the inverter current. The selection of the optimal voltage vector aims to minimize the error between reference and predicted current, using a cost function. Then, Perturb and Observe Maximum Power Point tracking algorithm is applied to the dc-dc boost converter for extracting maximum power from the photovoltaic array. Simulation and experimental results confirm the effectiveness of the proposed control method in terms of total harmonic distortion and power factor correction.

Keywords – *Predictive current control, Power quality, Photovoltaic system, harmonics.*

Abstract

EFFICIENT ENERGY MANAGEMENT FOR AN ELEVATOR SYSTEM UNDER A CONSTRAINED OPTIMIZATION FRAMEWORK

T. Hung Pham, I. Prodan, D. Genon-Catalot and L. Lefevre

Abstract – This work considers a constrained optimal control for the load in a DC microgrid elevator system (see Figure 1 and Paire (2010)). The mentioned microgrid includes batteries, supercapacitors, solar panels and a load system. The latter is composed by a mechanical elevator and a Permanent Magnet Synchronous Machine (PMSM). All these microgrid components are connected together through the DC bus and associated converters. The microgrid system is connected to the three phase electrical grid through a DC/AC converter. Having as global objective the minimization of the purchasing/selling electricity cost within the microgrid (Pham et al. (2017)), we concentrate here on the dissipated energy minimization while respecting constraints for the load and the associated AC/DC converter. By assuming that the dissipation on the mechanical elevator and on the converter is negligible, only the dissipation on the machine is taken into account. The considered constraints include the limits on the currents, voltages, machine speed and elevator position. A well-known method which deals with the constraints and cost is Model Predictive Control (MPC) (Rawlings and Mayne (2009)). However, using MPC with a long prediction horizon requires a high computation capacity which is not always available. Thus, we choose here to address the off-line reference profile generation and the on-line tracking control. In this work, we use differential flatness (Lévine (2009)) and B-spline-based parametrization (Suryawan (2011)) for respecting the system dynamics and state and input constraints. On-line we employ through the use of MPC the optimal reference profile tracking. The results are validated in simulation under different scenarios.

SUPERCAPACITOR CHARACTERIZATION USING FLUCTUATING DC-CURRENT FOR MICROGRIDS APPLICATIONS BASED ON WIND AND TIDAL ENERGIES GENERATION SYSTEMS

K. Bellache, M.B. Camara, and B. Dakyo

Abstract - This paper presents the supercapacitor parameters variations due to impacts of the DC-current frequency in ambient temperature tests conditions. The goal of this study consists to show the parameters evolution which can serve to determine the lifetime of supercapacitor for different conditions of use. The contribution of the paper is focused on the DC-current frequency impacts characterization for supercapacitor resistance and capacitance. The proposed method uses several DC-current profiles based on fluctuations and no fluctuations consideration. To do the supercapacitors characterization, the experimental tests based on charge and discharge operations with dynamic (fluctuating) DC-current are done. The experimental tests results are presented and analysed.

ADVANCED PASSIVITY-BASED CONTROL FOR A FUEL CELL/SUPER-CAPACITOR HYBRID POWER SYSTEM

S. Kong, M. Hilairet, R. Roche

Abstract - An advanced passivity-based control is proposed to solve the converters coordination problem of a fuel cell/super-capacitor hybrid power system. Interconnection and Damping Assignment Passivity Based Control (IDA-PBC) is applied to design the controller. This nonlinear controller considers the state-of-charge of the super-capacitor and achieves the stability of the whole closed-loop system. Its feasibility for an electrical vehicle is proven by simulation results and a comparison with an earlier method.

Keywords – Energy Management, Fuel Cell, IDA-PBC, Passivity Based Control, Super-capacitors.

STORAGE MANAGEMENT OF GRID CONNECTED PV PRODUCTIONS FOR EFFICIENT SELFCONSUMPTION IN BUILDINGS

J.Arkhangel'ski, M. Abdou Tankari, G.Lefebvre

Abstract - While the development of a real-time, proactive, and smart grid promises to solve energy problems in the long term, consumers and businesses need effective and affordable solutions today for managing their energy consumption and costs. Intelligent energy management technologies can provide these immediate solutions. This paper describes a method of storage management of grid connected PV productions for efficient self-consumption in buildings. It introduces the concept of Multifunctional converter that ensures the power flux in the Hybrid Renewable Energy Systems (HRES) with its functionalities, the power management strategies and some sizing parameters. Results of experimental tests are presented and analyzed.

Keywords – Hybrid renewable energy system, PV, Energy management, Energy storage, Buildings.

Efficacy

AC OR DC GRID FOR URBAN RAILWAY STATION?

Lilia GALAI DOL, Alexandre De Bernardinis

Abstract - The energy consumption of urban railway stations is huge and still being higher. To reduce the national electrical grid consumption, the first step is optimizing the equipment (size and regulation) and the second step is adding electrical sources like the train residual braking energy. Many of local energies productions are Direct Current (DC) ones. The actual internal station grid is in Alternative Current (AC) but the majority of the equipment has an AC/DC converter to be supplied with DC. This paper describes the project "urban railway station pole" led by the French EFFICACITY Institute, which concerns the use of the train braking energy and to develop the more adapted station grid. A comparison between AC and DC solution will be developed and discussed regarding global efficiency, complexity and control issues.

MANAGEMENT CONTROLLER FOR A DC MICROGRID INTEGRATING RENEWABLES AND STORAGES

Alessio Iovine, Gilney Damm, Elena De Santis, Maria Domenica Di Benedetto

Abstract - DC MicroGrids present an increasing interest as they represent an advantageous solution for interconnecting renewable energy sources, storage systems and loads as electric vehicles. A high-level management system able to calculate the optimal reference values for the local controllers of each of the DC MicroGrid interconnected devices is introduced in this paper. Both the changing environmental conditions and the expected load variations are taken into account. The controller considers power balance and the desired voltage level for the DC microgrid. Constraints taking into account the different nature of the storage devices are also considered.

COMPARISON OF MPC AND SDDP TO MANAGE AN URBAN DISTRICT PROBLEM DECOMPOSITION

François Pacaud, Pierre Carpentier, Michel de Lara

Abstract - Uncertainty are a common challenge in optimization: the fact that we cannot predict effectively the future limits the performance of optimization algorithms. In this presentation, we show a comparison of two algorithms to manage a small urban district while considering uncertainties. The first, MPC, tackles uncertainties with deterministic forecast and solve convex optimization problems to compute decisions for all time t . The contender, Stochastic Dual Dynamic Programming (SDDP), computes a lower-approximation of Bellman's value functions and solves at each time t an optimization problem that considers effectively the uncertainty. We present a detailed comparison of these two algorithms, and then show that stochastic optimization algorithms may be effective to manage systems confronted to uncertainty. Eventually, we will introduce some hints to extend this work in a decentralized fashion.

A NOVEL CONTROL STRATEGY FOR THE DAILY OPTIMAL MANAGEMENT OF A VENTILATION SYSTEM IN A SUBWAY STATION

Marouan Sabah, Alexandre De Bernardinis

Abstract - In the frame of collaborative research coordinated by Efficacy Institute, including IFSTTAR, consist in reducing the energy consumption in urban subway station, considering the passenger comfort (like the air-quality). The main challenge is to improve the existing material with new operating mode and limited intrusive actions without any influence on the current maintenance operations. A station electrical consumption investigation made in Paris metro has shown that almost the half of stations consumers are motors (ventilation, escalators, lifts, pumps etc...). A novel approach for electrical daily management of subway station ventilation applied to a microgrid was developed. The main ventilation constraints: the "piston effect" caused by the train air pressure was modelled. The high-level control is an airflow management considering external data (Air quality, temperature...) and don't reduce the equipment life. This control input was converted according to the motor low-level speed control strategy in order to improve the motor dynamics.

TWO TIME SCALES STOCHASTIC DYNAMIC OPTIMIZATION FOR MICROGRIDS CONTROL

Pierre Carpentier, Jean-Philippe Chancelier, Michel De Lara, Tristan Rigaut

Abstract - Microgrids control architecture is often decomposed into multiple levels to handle multiple time scales. Voltage and power stability have to be ensured every seconds while energy tariff arbitrage is made between different hours of the day. We focus on microgrids with energy storage that is used to mitigate renewable production and demand uncertainty. Such dynamical systems can be managed using Stochastic Optimal Control (SOC) techniques. However the interaction between multi-time scales decisions and uncertain phenomenon requires to model the optimization problem with a massive amount of time steps. It is therefore not straightforward to apply classical methods such as Stochastic Dynamic Programming (SDP) or Model Predictive Control. We propose hereby a methodology to model optimization problems with multiple time scales as well stochasticity and information revelation throughout time. We present a method based on SDP by blocks to solve that kind of problems. Finally we apply the theory to the management of an energy storage for intraday energy arbitrage and long term ageing.

Abstracts

SECURE STATE ESTIMATION FOR DC MICROGRIDS CONTROL

Gabriella Fiore, Alessio Iovine, Elena De Santis, Maria Domenica Di Benedetto

Abstract - Hierarchical control composed by different levels is usually adopted in DC Micro-Grids and communication among the controllers is utilized to ensure grid stability. The exchanged information is assumed to be shared by means of a (wireless) communication network, which can be compromised by a malicious attacker. The attack is here not represented by a specific model, but it is assumed to be unbounded and influencing only a small subset of sensors (which is fixed over time). To the aim of having a secure exchange of data, a secure state estimation is performed.

DESIGN AND CONTROL OF A DC GRID FOR RAILWAY STATIONS

Sabah SIAD, Gilney DAMM, Lilia GALAI DOL, Alexandre DE BERNARDINIS

Abstract - With growing concerns about environmental issues like climate change, energy efficiency has become crucial. In this framework, the regeneration of the braking energy of trains into electricity is a promising source to highly increase energy efficiency. The focus of this paper is to Design and Control a Direct Current (DC) Grid integrated in urban railway station, the solution consists in recovering and storing trains braking energy into a hybrid storage system and reusing it for non-railway applications such as loads in a train station and electric vehicles and their recharging plants. To attain this goal, the main points are power management and voltage control for the DC Micro-Grid, and improving the dynamic performance of the system. These are obtained by controlling the energy storage system.



GT Micro-réseaux, SEEDS

DATAZERO: DESIGNING AND OPERATING DATACENTERS POWERED BY RENEWABLE ENERGY-BASED STAND-ALONE MICROGRIDS

R. Roche, S. Caux, J. Lecuivre, J.-M. Pierson, D. Hissel, J.-M. Nicod (FEMTO-ST, LAPLACE, EATON Industries France, IRIT)

Abstract – This paper describes the DATAZERO project, which focuses on the design and operation of datacenters powered by renewable energy and without any emission of greenhouse gas. It describes the selected supply system architecture, in the form of a stand-alone microgrid, as well as the proposed modules for the operation of both power and information technology (IT) sides. The operation philosophy relies on a negotiation between both sides, i.e., between using (and aging) components and reducing the quality of service for IT tasks.

Keywords – *datacenter, microgrid, renewable energy, degradation, energy management.*

MODELLING AND LOAD BALANCING OF A DC MICROGRID USING PORT-HAMILTONIAN FORMULATION

Igyso Zafeiratou, Ionela Prodan, Laurent Lefèvre, Laurent Piétrac (LCIS, AMPERE)

Abstract – In this work, we present the model of a DC microgrid, composed by a solar panel, an energy storage system, a utility grid and a group of interconnected loads (housing and office equipment, electrical vehicles). The transmission lines connect the energy sources with the loads through the corresponding switching DC/DC converters. The dynamical model of an initial and a more extended architecture of the system is developed through the use of port Hamiltonian formulations. In view of system control and optimization we formulate the load balancing problem of the DC microgrid in order to stabilize the power flow within the DC bus among the different parts of the DC microgrid. The obtained results are validated through numerical simulations.

Keywords – *datacenter, microgrid, renewable energy, degradation, energy management.*

MODELING AND LARGE SIGNAL STABILITY ANALYSIS FOR ISLANDED AC-MICROGRIDS

H. Moussa, J-P. Martin, S. Pierfederici (GREEN)

Abstract – It is well known that the dynamic interaction between Distributed Generators (DG) and loads in a microgrid (MG) results to unstable behavior depending on the type of load being connected. Stability of AC-MG is influenced by high penetration of tightly regulated power converters used to interface distributed resources and loads. In this case, load converters behave as constant power loads (CPL) and introduce a negative incremental resistance feature which reduces the system stability. This paper addresses the Large-Signal stability analysis of AC microgrid to understand the effect of each type of load in MG stability.

Keywords – *Microgrids, Constant power load (CPL), System stability, Large-Signal analysis.*

SHORT CIRCUIT PROTECTION OF A DC-DC CONVERTER IN DC MICROGRID

Thi Thuong Huyen Ma, Hamed Yahoui, Hervé Morel, Hoang Giang Vu, Nicolas Siauve (AMPERE)

Abstract – Protection is one of the most challenges in the development of distributed DC grid. This paper proposes a protection scheme in which DC-DC converters have the same function as DC circuit breakers. The desaturation principle is employed to detect drainsource voltage of the switching devices through a diode under overcurrent condition. The enable signal is sent to activate a forward-flyback converter to turn off all switches of the converter. Therefore DC-DC converters can fast limit and interrupt fault current in order to ensure the safety for the system. The experimental results show that the converter is able to clear faults in some microseconds.

Keywords – *DC microgrid protection, current limiting, short-circuit protection.*

STAND-ALONE MICROGRID SIZING CONSIDERING ELECTRIC/HEATING/COOLING AND HYDROGEN DEMANDS

Bei Li, Robin Roche, Damien Paire, Abdellatif Miraoui (FEMTO-ST, FCLAB)

Abstract – A microgrid is a small-scale power system which typically includes local generation, storage and a control unit. Building an effective microgrid requires both adequate sizing and operations. In this paper, we present a co-optimization method to size a standalone microgrid which considers electric, heating, cooling and hydrogen demands. The operation strategy is formulated as a mixed-integer linear programming (MILP) problem, and a genetic algorithm (GA) is used to search for the sizing values for each component. Simulation results show the feasibility of the sizing method.

Keywords – *sizing, energy management, microgrid (MG), multi-energy system, unit commitment.*

RAILWAY STATION INTEGRATED SMART GRID AT SNCF

Nanfang YANG; Tony LETROUVE; Guillaume GAZAIGNES (SNCF)

Abstract – Facing the global warming thereat, the French railway system group has an objective to cut 25% of CO₂ emission and 20% of energy consumption by 2025 from 2014. This abstract introduces the concept of railway station integrated smart grid at SNCF, to promote more energy-efficient, environment friendly railway stations.

GT RSEI, MACS

ANALYSIS AND QUANTIFICATION OF UNCERTAINTIES – SIZING AND MANAGEMENT OF ELECTRICAL SYSTEMS WITH A HIGH LEVEL OF RENEWABLE ENERGY

Bruno François

The massive development of intermittent renewable energy technologies in power systems affects the operation of electrical systems. Due to technical limitations and required investments to maintain the current electrical security level, issues related to dispatching, static and dynamic stability could stop the development of these distributed renewable energy sources (RES). Renewable energy production is predictable as well as the load demand but with an increasing forecasting error if the time horizon is distant.

For operational planning, a tool to study the uncertainties of PV power and load forecasting in an urban microgrid will be presented. With stochastic methods, the day-ahead operating reserve (OR) can then be quantified by taking into account an associated reliability risk index. Then the OR is dispatched into different power generators (active PV generators and micro gas turbines). To minimize the microgrid total operational cost and/or equivalent CO₂ emissions, day-ahead optimal operational planning and dispatching of the OR into different power generators is implemented. Finally, a freeware “A User-friendly Energy Management System and Operational Planning Supervisor” is developed on the Matlab GUI to conceptualize the overall system operation.

For the technical and economic analysis of investments in future electrical networks, uncertainty analysis can be also developed and embedded in decision support software. An application will be presented regarding the cost assessment of an electrical system for the connection of an offshore wind farm park. Uncertainties in economic models and estimation of future annual electrical losses are taken into account into a proposed probabilistic analytical method.

Keywords – *Uncertainty analysis, energy management, microgrid, power reserve dispatching, reliability, renewable energy, unit commitment problem.*

Biography: Bruno Francois received the PhD degree in electrical engineering in 1996 from the University of Science and Technology of Lille (USTL), France. He is Professor at the Department of Electrical Engineering of Ecole Centrale de Lille and researcher at the Laboratory of Electrical Engineering (L2EP) in the Power System group. He is currently working on the design of advanced energy management systems, uncertainty analysis in power system applications and future electrical network architectures.

MVDC FOR SMART-CITIES: MYTH OR REALITY?

Philippe EGROT, Power Grid Senior Engineer EDF – R&D Electrical Equipment Laboratory

Abstract – Direct current for High Voltage transmission systems is a real opportunity to reduce losses and offer many new ancillary services. But does that also concern large cities with overloaded electrical income feeders ?

RECHARGING GAMES FOR ELECTRIC VEHICLES

Samson LASAULCE - RTE Chair on the Digital Transformation of Electricity Networks

Abstract – The target of this presentation is to introduce the electric vehicles recharging problem as a game. To this purpose, a small tutorial will be provided. To the purpose to measure the impact on the distribution network in particular, several recharging algorithms will be introduced and tested. Three possibilities of how to define a recharging algorithm will be discussed, as using a static game formulation or an optimal control one or using digital tools dedicated to solve Markov decision processes.

DISTRIBUTED NONLINEAR CONTROL FOR DC MICROGRIDS: A TRAIN STATION CASE STUDY

Alessio Iovine, Lilia Galai-Dol, Gilney Damm, Elena De Santis, Maria Domenica Di Benedetto

Abstract – A low-level distributed nonlinear controller for a DC MicroGrid integrated in a Train Station is introduced. A number of elements are connected to the MicroGrid: two different transient time scale renewables (braking recovery and photovoltaic), two kinds of storage acting at different time-scale (a battery and a supercapacitor), and a load. The model is developed and a complete stability analysis is investigated: power balance and voltage grid stability requirements are both met. A System of Systems approach is utilized to develop the control laws for the DC/DC converters in order to fulfil the dedicated objective each controller has. Simulation results showing the desired grid behaviour are presented.

DATAZERO: DESIGNING AND OPERATING DATACENTERS POWERED BY RENEWABLE ENERGY-BASED STAND-ALONE MICROGRIDS

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Abstract – This paper describes the DATAZERO project, which focuses on the design and operation of datacenters powered by renewable energy and without any emission of greenhouse gas. It describes the selected supply system architecture, in the form of a stand-alone microgrid, as well as the proposed modules for the operation of both power and information technology (IT) sides. The operation philosophy relies on a negotiation between both sides, i.e., between using (and aging) components and reducing the quality of service for IT tasks.

Keywords – datacenter, microgrid, renewable energy, degradation, energy management.

1. INTRODUCTION

In a context of rising climate change consequences, it has become crucial to facilitate the development of greener datacenters, capable to operate without emission of greenhouse gases [1]. The DATAZERO project, funded by the French National Research Agency from 2015 to 2019, brings together academic (FEMTO-ST, IRIT, LAPLACE) and industry (EATON) partners to help tackle challenges related to the design and operation of MW-scale datacenters solely powered by renewable energy.

2. MICROGRID STRUCTURE

The proposed power supply system is a stand-alone microgrid (Fig. 1). It includes renewable energy sources in the form of PV panels and wind turbines, storage units, in the form of supercapacitors, batteries (for short-term storage), and hydrogen storage (combining fuel cells, tanks and an electrolyzer for seasonal storage). This structure enables meeting all datacenter power and energy requirements without any direct emission, and while considering load and generation dynamics.

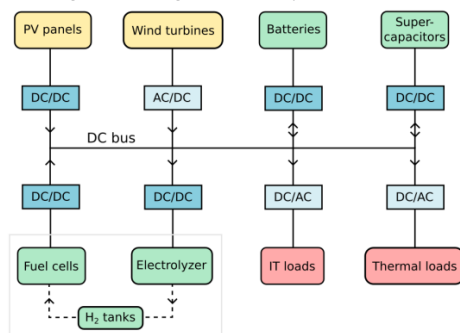


Fig. 1. Datacenter power supply infrastructure.

3. SIZING AND ENERGY MANAGEMENT

Models of these different components are established, and include degradation processes which reduce components

performance over time. These models are then used for determining the optimal size of the components, and in the modules described in Fig. 2. For example, the power decision module (PDM) is in charge of scheduling the operation of the components in advance, and of dispatching the power load in real time among the components, accounting for forecasting errors. A similar module (ITDM) exists on the IT side for scheduling IT tasks on servers.

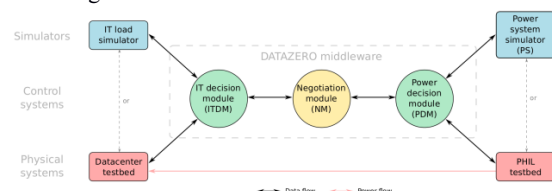


Fig. 2. Overview of the DATAZERO modules.

The negotiation module then handles a negotiation with the IT side to determine the datacenter operation. For example, in the advent of a sudden decrease in PV output, the system can decide to discharge the batteries, or to postpone some IT tasks to be run on the servers.

After simulations will have enabled to verify the correct operation of the designed models and algorithms, a reduced scale power hardware-in-the-loop (PHIL) experiment will be conducted to validate the proposed systems.

ACKNOWLEDGEMENT

This work was supported by the French Research Agency under the project DATAZERO (ANR-15-CE25-0012).

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Modelling and load balancing of a DC microgrid using port-Hamiltonian formulation

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In this work, we present the model of a DC microgrid, composed by a solar panel, an energy storage system, a utility grid and a group of interconnected loads (housing and office equipment, electrical vehicles). The transmission lines connect the energy sources with the loads through the corresponding switching DC/DC converters. The dynamical model of an initial and a more extended architecture of the system is developed through the use of port Hamiltonian formulations. In view of system control and optimization we formulate the load balancing problem of the DC microgrid in order to stabilize the power flow within the DC bus among the different parts of the DC microgrid. The obtained results are validated through numerical simulations.

Keywords: *Control modelling, Port-Hamiltonian method, Power flow, Load balancing*

I. Information about the project

The DC microgrid considered in this project (fig.1) consists of different types of physical components, as mentioned before, and it can operate either connected to the utility grid or autonomously as a stand-alone system. This work is carried out within the *C3μ* (Components, Control and Communication) ANR project which started in March 2016. The main goal is to investigate the energy savings potential, benefits and safety of using a meshed DC-grid for delivery of electrical energy in the interior of a building and to associate in a more efficient way the integration of renewable energy sources into a unit of buildings.

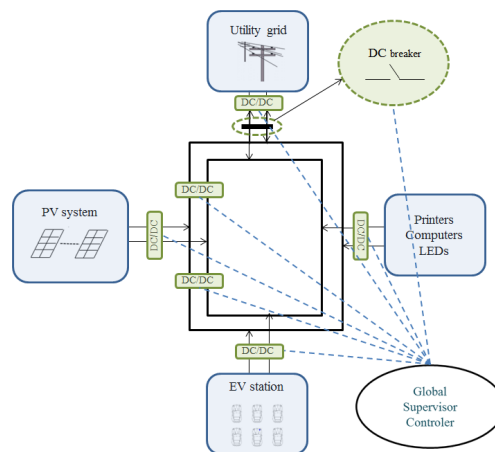


Figure 1. Extended architecture of the DC microgrid

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MODELING AND LARGE SIGNAL STABILITY ANALYSIS FOR ISLANDED AC-MICROGRIDS

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Abstract - It is well known that the dynamic interaction between Distributed Generators (DG) and loads in a microgrid (MG) results to unstable behavior depending on the type of load being connected. Stability of AC-MG is influenced by high penetration of tightly regulated power converters used to interface distributed resources and loads. In this case, load converters behave as constant power loads (CPL) and introduce a negative incremental resistance feature which reduces the system stability. This paper addresses the Large-Signal stability analysis of AC microgrid to understand the effect of each type of load in MG stability.

Keywords – Microgrids, Constant power load (CPL), System stability, Large-Signal analysis.

1. INTRODUCTION

In literature, modeling and stability analysis of microgrids are extensively studied [1]–[3]. However, the major stability studies are based on small-signal linearization techniques [3]. Where the non-linear model is linearized around an operating point and then studied by using linear analysis tools. It is well known that small-signal stability studies are only valid around the operating point and limited for a local domain of variation. Thus, only small perturbations can be explored with small-signal analysis.

In this paper, the large-signal stability analysis of ac microgrid with different load interaction is studied. First, a nonlinear model for inverter based microgrid is constructed taking into account the inverter inner controller, virtual impedance loop and different load types. Then, the domain of attraction of the system is developed based on Marx *et al.*'s approach [4]. The effect of different types of load on the domain of attraction is studied. Furthermore, the effect of virtual impedance loop on system stability is investigated.

2. SYSTEM MODELING AND RESULTS

Fig. 1 shows a simplified diagram for the microgrid system, where N -Distribution Generators (DGs) supply a CPL load, resistive load and a constant current load represented by a current source. Every DG in a microgrid includes a voltage source inverter (VSI), a local controller and an outer power droop controller. In order to formulate equations describing a DG system, we consider only the dynamics of the inner controller and the virtual impedance loop by neglecting the model of the droop control. We consider that the droop control is perfectly designed and the poles associated to the dynamics of the droop are weakly affected by the load interaction and consumed power change.

2.1. LARGE SIGNAL STABILITY ANALYSIS TOOL

Takagi-Sugeno (TS) multi-modeling is used to determine the estimated domain of attraction.

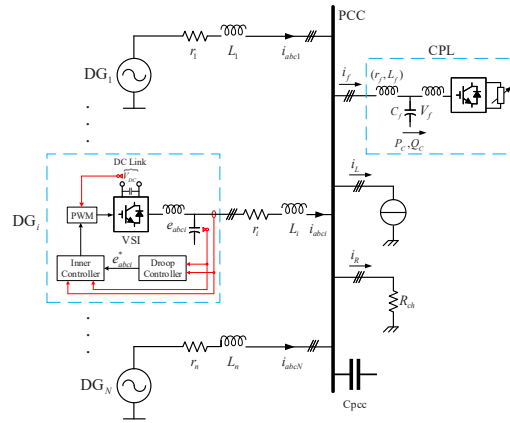


Fig. 1 Single-line Diagram of the Microgrid system under study.

TS multi-model is a useful tool for studying the stability of nonlinear system. In order to use Lyapunov method for the TS model, Marx *et al.* [4] state that the system is asymptotically stable if the following $r + 1$ Linear Matrix Inequalities (LMI) hold:

$$\begin{aligned} M &= M^T > 0 \\ A_i^T \times M + M \times A_i &< 0, \quad i \in \{1, 2, \dots, r\} \end{aligned} \quad (1)$$

Once the matrix M is determined, the following Lyapunov is completely known:

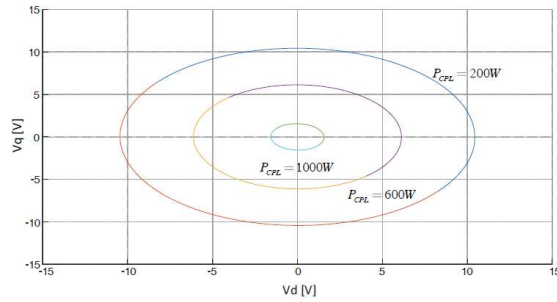
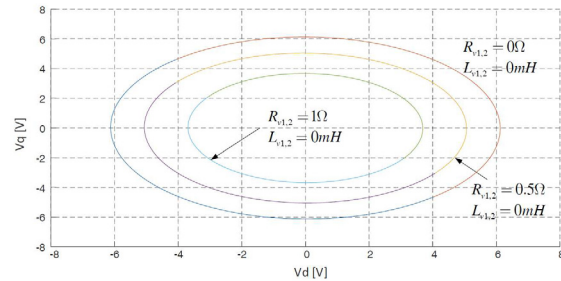
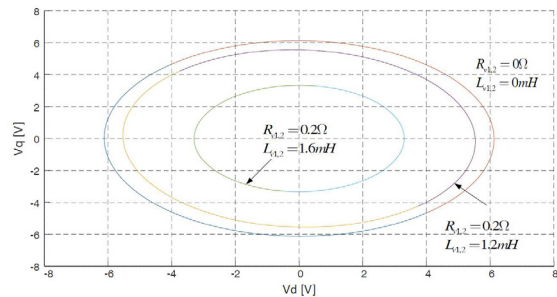
$$V(x) = x^T \times M \times x \quad (2)$$

2.2. RESULTS

A MATLAB simulation is implemented to solve LMI for the nonlinear model. The system parameters used in simulation are given in Table I. Following the algorithm, the min. and max. values of dq voltages were obtained, and the estimated domain of attraction is plotted in the x_5 - x_6 plane (i.e. v_{PCCd} - v_{PCCq} plane). The effect of CPL load in the domain of attraction is first studied. Fig. 2 shows the estimated domain of attraction for three values of CPL active power. It can be noticed that, as the power of the CPL increases the domain of attraction become narrower. This interprets the destabilizing effect of the CPL on ac-MG when connected to some intensive active loads.

TABLE I. SYSTEM PARAMETERS FOR SIMULATION

System frequency/voltage (ω, V_n)	$2\pi 60 \text{ rad/s}, 110 \text{ V RMS}$
PCC Capacitor bank C_{PCC}	100 nF
Feeder 1 (r_1, L_1)	$(0.1 \Omega, 1 \text{ mH})$
Feeder 2 (r_2, L_2)	$(0.1 \Omega, 1 \text{ mH})$
CPL input filter (r_f, L_f, C_f)	$(0.1 \Omega, 0.4 \text{ mH}, 40 \mu\text{F})$
DG1 Voltage controller (ξ_1, ω_{c1})	$(1, 5000 \text{ rad/sec})$
DG1 Voltage controller (ξ_2, ω_{c2})	$(1, 5000 \text{ rad/sec})$


 Fig. 2. Estimated Domain of attraction for the system under the effect of CPL active power ($R_{ch}=100\Omega, I_{Ld}=0, I_{Lq}=-3 \text{ A}$).

 Fig. 3. Effect of virtual resistance R_v on the estimated domain of asymptotic stability. Load consumption: P_C (CPL) = 600 W , $R_{ch}=1000\Omega, I_{Ld}=0, I_{Lq}=-3 \text{ A}$.

 Fig. 4. Effect of virtual inductance L_v on the estimated domain of asymptotic stability. Load consumption: P_C (CPL) = 600 W , $R_{ch}=1000\Omega, I_{Ld}=0, I_{Lq}=-3 \text{ A}$.

As a speculation, one can say that a virtual impedance is a solution to damp oscillation coming from loads. But, in reality, the effect of virtual impedance on high-frequency range is bound to inverter voltage controller. Furthermore, adding a virtual impedance to the output of

the DG in series with the feeder impedance will have a destabilizing effect on the MG-system. To illustrate this, we did a test with inverters having a bandwidth equal 5000 rad/sec which is less than the oscillating frequency generated by the input filter of the CPL which is around $8 \times 10^3 \text{ rad/sec}$. Fig. 3 shows a case study, where the domain of attraction region is plotted for three values of R_v which is the virtual resistance introduced in the two inverters inner controller. It can be seen that the domain of attraction decreases as the virtual resistance increases. Thus, the virtual resistive component has a negative effect on the stability of the microgrid with intensive use of CPL load. Similarly, the effect of virtual inductive impedance is realized. It should be noted that, the virtual inductance is usually used in microgrid application to enhance the reactive power sharing. For that reason, its effect on the stability of microgrid should be elaborated. In Fig. 4 the domain of attraction region is plotted for different values of virtual inductive impedance. As the value of L_v increases, the estimated domain of attraction decreases. Exceeding a value of $L_v=1.6 \text{ mH}$ will allow the system to lose stability.

3. CONCLUSION

The large signal stability for ac microgrid was explored. The study focuses on the effect of load interaction with the ac-MG. The effect of CPL load on the estimated domain of attraction was realized. Furthermore, the effect of virtual impedance loop in system stability is pointed out. It should be noted that, the virtual impedance loop is commonly used to compensate reactive power sharing for droop control based-microgrids. The aforementioned results, show that the virtual impedance loop has a negative impact on system stability and additional impedance loop tends to destabilize the system especially when supplying a CPL load. One opinion that should be verified in the future, is the use of parallel virtual resistive impedance. In this case, the virtual impedance loop could damp oscillations result from different load interactions.

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Railway Station Integrated Smart Grid at SNCF

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Facing the global warming threat, the French railway system group has an objective to cut 25% of CO₂ emission and 20% of energy consumption by 2025 from 2014. This abstract introduces the concept of railway station integrated smart grid at SNCF, to promote more energy-efficient, environment friendly railway stations.

1. INTRODUCTION

Facing the global warming threat, French railway system group, including SNCF, SNCF MOBILITÉ, and also SNCF RÉSEAU, has an objective to reduce 25% of CO₂ emission and 20% of energy consumption by 2025 from 2014. In the other way, SNCF group is always engaged to provide a convenient, energy-efficient and green transportation way for all customers. To achieve those objectives, we propose the concept of railway station integrated smart grid, in order to integrate renewable energies, energy storage system, as well as electric vehicle charging station together within the railway station. Besides, the aggregation of railway stations gives us the opportunity to participate into demand-side response so as to contribute to the balancing of power grid.

2. SYSTEM AND OPERATION

The railway station integrated smart grid can be divided into two layers as shown in Figure 1. From bottom to top, they are local microgrid and aggregator, respectively.

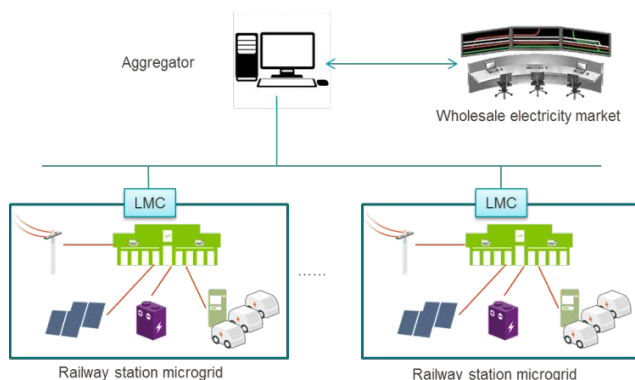


Figure 1 The structure of railway station integrated smart grid

Local renewable energy resources, e.g., rooftop PV panels, batteries, EV charging station, even the diesel generators for railway signaling system can be grouped together to form a station microgrid. It supplies power for the lighting, heating, ventilation system of the railway station, as well as other electronic equipment, such as ticket vending machines. The microgrid is connected to low-voltage distribution grid, and it can be managed by a local microgrid controller (LMC) to optimize the energy consumption of the railway station.

The aggregator in the top layer focuses on the participation of demand-side response program and coordinate control of multiple station microgrids. In microgrids side, it collects

the information about controllable loads in order to estimate the potential power to be shaved, taking into consideration the uncertainties of energy consumption. In market side, it represents the railway stations as a whole to buy energy and bid shaving energy in the wholesale electricity market, e.g., EPEX Spot. Besides, the aggregator takes in charge of the communication with transmission/distribution grid operator to supply ancillary grid services.

3. RAILWAY STATION MICROGRID

Several demonstration projects are planned in some TGV stations. The main objective of those projects is to improve the energy efficiency. Rooftop PV panels and energy storage system would be installed in some stations. Several sensors will be installed in the station to measure temperature, air quality, etc. The local microgrid controller LMC takes those measurements and also real-time electricity price to manage the lighting, HVAC system and energy storage.

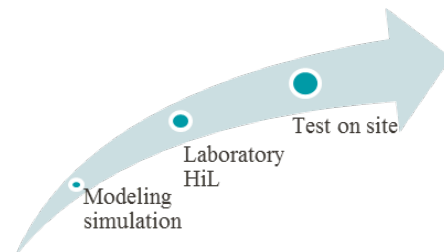


Figure 2 Development path of railway station microgrid

The development of railway station microgrid can be divided into three phases, as shown in Figure 2. At first, the model of railway station microgrid will be constructed to run simulations off-line; then a real LMC with the corresponding control algorithm will be connected with the model of microgrid to verify its functioning in our laboratory. Finally, the tested LMC will be installed on site to analyze the profitability of the project.

4. CONCLUSION

This abstract introduce the application of microgrid in railway stations, with the aim to achieve better energy efficiency and lower CO₂ emission for railway service. The aggregation of multiple railway microgrids allows us to participate into the liberalized electricity market and to supply ancillary grid service. This would help to open a new business for the railway system operators.

SHORT CIRCUIT PROTECTION OF A DC-DC CONVERTER IN DC MICROGRID

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Abstract – Protection is one of the most challenges in the development of distributed DC grid. This paper proposes a protection scheme in which DC-DC converters have the same function as DC circuit breakers. The desaturation principle is employed to detect drain-source voltage of the switching devices through a diode under overcurrent condition. The enable signal is sent to activate a forward-flyback converter to turn off all switches of the converter. Therefore DC-DC converters can fast limit and interrupt fault current in order to ensure the safety for the system. The experimental results show that the converter is able to clear faults in some microseconds.

Keywords – DC microgrid protection, current limiting, short-circuit protection.

1. INTRODUCTION

Up to now, many studies have illustrated the advantages of DC distributed grids in relation to AC grids in higher energy efficiency, simpler control, easier integrated with renewable energy resources, energy storage systems, electronic loads and more reliable in operation [1]. Recent research mainly concentrates on the control strategies and energy managements, while the protection receives inadequate attention that may lead to the lack of understanding and experiences. Protection in DC grids is more difficult than that in AC grid due to the continuous arc, higher short circuit current value and fault rate of rise. Furthermore, in the DC distributed grids are composed of many electronic and semiconductor switching devices, which should be able to withstand the over current from 3 to 5 times rated values in some microseconds. In order to ensure the safety of these systems, the protection devices have to interrupt the faults in a shorter time. Some literatures indicated that converters could be used as circuit breakers (CBs) in a simple way by turning off all their switching devices. Voltage source converters have function like a current limiting CBs to clear and localizing a fault [2]. Protection relay were utilized to detect the short circuit current and send the signals to turn-off all the switches. In [3] an ultra-fast DC-DC converter was designed to protect for a voltage fed inverter with the response time of 60 μ s, much higher than the requirements.

This paper proposed a short circuit protection scheme for a DC-DC converter, which uses normally-on SiC JFETs as main switches. The short-circuit protection function of the converter is separated with the driver and consists of two key components: Detection circuit and forward flyback converter. The experimental results for the forward flyback converter prototype (fig.1) when it is applied a voltage of 5V to the primary shows that it can turn-off JFET in 5 μ s (fig.2).

The tests for all protection parts will be done in next time.

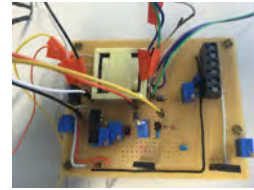


Fig. 1. Forward-flyback converter prototype .

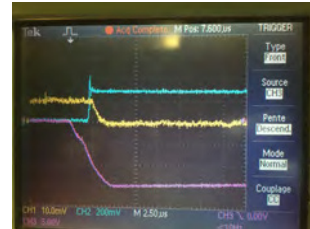


Fig. 2. Turn-off JFET by using the proposed forward-flyback converter. BLUE is V_{ds} (5V/div), Yellow is I_{ds} (0.1A/div), Pink is V_{gs} (5V/div), Time (2.5 μ s/div)

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STAND-ALONE MICROGRID SIZING CONSIDERING ELECTRIC/HEATING/COOLING AND HYDROGEN DEMANDS

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Abstract – A microgrid is a small-scale power system which typically includes local generation, storage and a control unit. Building an effective microgrid requires both adequate sizing and operations. In this paper, we present a co-optimization method to size a stand-alone microgrid which considers electric, heating, cooling and hydrogen demands. The operation strategy is formulated as a mixed-integer linear programming (MILP) problem, and a genetic algorithm (GA) is used to search for the sizing values for each component. Simulation results show the feasibility of the sizing method.

Keywords – sizing, energy management, microgrid (MG), multi-energy system, unit commitment.

1. INTRODUCTION

The adequate size of microgrid components depends on the selected operation strategy. Oversizing leads to excessive investment costs, while undersizing results in load shedding or curtailed power. In this paper, we present a co-optimization method to size a stand-alone microgrid considering electric, heating, cooling and hydrogen demands. For electricity, The hydrogen storage system is used for long-term storage, and the battery for the short-term. The structure of such microgrid system is shown in Figure 1.

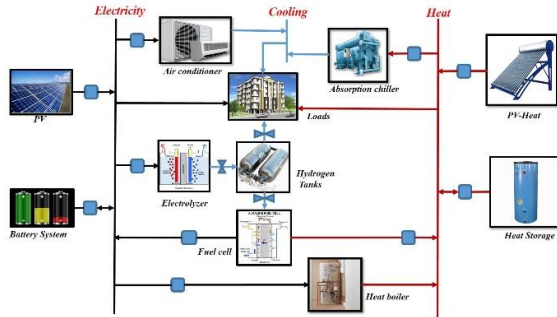


Fig. 1. Multi-energy microgrid structure.

2. SIZING PROBLEM

2.1. CO-OPTIMIZATION FRAMEWORK

A genetic algorithm is used to compute the optimal size of the components that minimize the total annual cost (capital, maintenance and operation) of the system. Each candidate solution (set of components sizes) is evaluated with the MILP UC algorithm. The co-optimization problem can be formulated as follows:

$$\min_{U \in \vec{U}} \left\{ C_{cap} + \min_{U^*, S} \left\{ C_{op} + \left\langle \min_{U^*, S^*} \{EENS\} \right\rangle \right\} \right\}$$

where \vec{U} is the set of sizing values of each component, C_{cap} is the capital cost of the system, C_{op} is the

operation cost, and $EENS$ is the load shedding or curtailed power.

The sizing values returned by the algorithm, namely, $U^* = \{N_{PV}, N_{sh}, CB, P_{fc}^{max}, P_{ele}^{max}, V_{h_2}, P_{hb}^{max}, P_{ac}^{max}, Q_{ahc}^{max}, HS^{max}\}$,

correspond to the number of PV panels, the area of solar heating, the capacity of the battery, the fuel cell rating, the electrolyser rating, the hydrogen tanks capacity, the heat boiler rating, the air conditioner rating, the absorption heat chiller rating, and the heat storage system capacity.

2.2. SIMULATION RESULTS

The cost parameters are adopted from [1], [2], [3]. The model is implemented in MATLAB and solved with Gurobi. Load demand data (for cooling, heat, electric power and hydrogen) and solar radiation are obtained from a research building, located in Belfort, France. Based on the above method, the obtained sizing results are shown in Table I. These results show the feasibility of the method, although further work has to be carried out to improve the method, e.g., by comparing it with other works.

Table I. Sizing results

N_{PV}	N_{sh}	CB	P_{fc}^{max}	P_{fc}^{ele}
327	43 m ²	735 kWh	131 kW	690 kW
ΔV_{h_2}	P_{hb}^{max}	P_{ac}^{max}	Q_{ahc}^{max}	ΔHS^{max}
84865 Nm ³	283 kW	159 kW	686 kW	3000 kWh

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SCALING OF WIND ENERGY CONVERSION SYSTEM

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Abstract - This paper presents a scaling methodology based on dimensional analysis and applicable to systems' mathematical models. The main goal of this research is to propose time-compressed HIL experiments together with reduced power, while keeping similarity with respect to the dynamics of the original system. The scaling process is presented using a simple wind turbine model. This reduced model is validated through a simulation in which the wind conversion system is connected to a scaled electrochemical battery.

Keywords – Wind System, Similarity, Scaled Systems, Time Acceleration, HIL.

1. INTRODUCTION

Emergence of new environmental objectives with the development of renewable energies require modern electricity networks. In this framework, modeling, simulation and experimentation become key issues.

Nevertheless, the experimental phase can be difficult when systems are complex. The related cost is huge especially for high power systems. As numerical simulations make possible to deduce the characteristics of the phenomena in real size, reduced scale physical emulation based on Hardware in the Loop (HIL) experiments minimize the risks associated with the experiments and decrease associated costs; such process aims at experimentally validate the simulations especially dynamic (real time) aspects related to control and management of power systems. Moreover, these similarity models allow to physically emulate systems in "compacted virtual time" making more efficient (more rapid) the validation process. The issues of similarity will have to achieve relevant scale reduction and so they are as useful in sizing models for system engineering as for models built into physical emulators.

The laws of physics are invariant with respect to any change of unity. This invariance notion is essential. It allows defining the behaviour of physical systems by a complete set of dimensionless variables formed by relevant physical variables. Then it is possible to compare the systems with each other by comparing their dimensionless quantities. The Vaschy-Buckingham theorem [1] (or Π theorem) allows to set how many dimensionless numbers can be constructed in a physical problem that involves n variables. In engineering, dimensional analysis is related to the relationships between physical quantities by identifying their fundamental dimensions. It is a powerful tool widely used for scale model [2], [3].

The main goal of this research is to propose time-compressed HIL experiments together with reduced power, while keeping similarity with respect to the dynamics of the original system. The scaling process is applied to a wind energy conversion system (Fig. 1). This reduced model is validated through a simulation. At the end, an experimental real-time validation is performed using physical emulators.

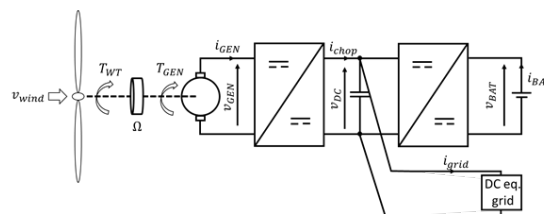


Fig. 1. Wind energy conversion system



Fig. 2. Smart microgrid testbench for investigation

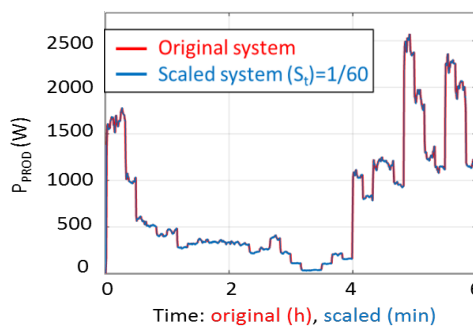


Fig. 3. Experimental validation

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I-V CURVE SCANNING IN PARALLEL ARCHITECTURE BASED ON DC SOLAR OPTIMISERS

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Abstract – Use of optimisers connected to individual photovoltaic (PV) modules allows new capabilities like survey of power for each module. In this paper we show that it is possible to extract I-V curves without stopping electricity supply in the case of parallel solar optimisers. Analysis of such data would make easier PV generator diagnosis, particularly in partial shadowing.

Keywords – DC micro-grid, Photovoltaic modules, Solar optimisers, I-V curves, Shadowing.

1. INTRODUCTION

Even if serial DC optimisers can be provided to survey every module in a PV generator, parallel solar optimisers [1] can be preferred for more capabilities like unplugging, for maintenance, without stopping electricity supply. In laboratory we have realised such devices [2] able to step up PV voltage to sufficient level to drive grid inverter or to implement DC micro-grid with storage capacities or not.

2. PV PARALLEL ARCHITECTURE

2.1. COUPLING OF DIFFERENT PV MODULES

Two polycrystalline modules (one of 40Wp, the other of 50 Wp) are coupled in parallel, thanks to boosts with high voltage ratio.

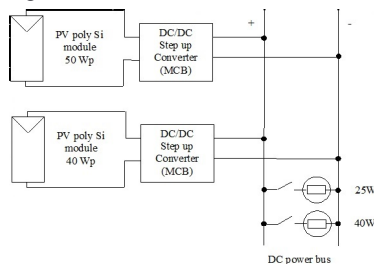


Fig. 1. Solar optimisers in parallel association.

2.2. LOADS CONNECTED TO POWER BUS

With aim to experiment parallel architecture in realistic condition with space requirements, incandescent lamps are chosen: they are able to dissipate energy in small volume and their transient variable impedance is useful to study behaviour of optimiser control laws [3] [4].

2.3. DATA ACQUISITION SYSTEM

I-V curves are drawn with data acquired in two different ways. The first one, considered as a benchmark, is a system integrating commercial USB acquiring module and cards specially developed in laboratory for conditioning analog signal. The second one is to use internal sensors of the boost: amount of acquired data is adjusted according to expected precision.

3. I-V CURVE SCANNING WITH MPPT

3.1. SCANNING OF PV MODULE WITHOUT SHADOWING

A Perturb and Observe algorithm, suitable for MCB converter designed in laboratory, is implemented in 40 Wp module converter as a specific program scans periodically 50 Wp module when incrementing duty cycle.

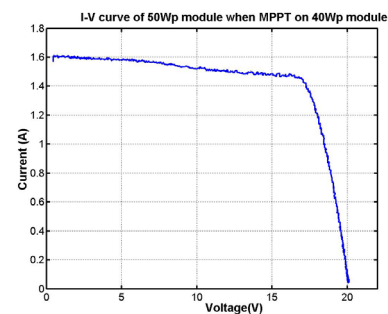


Fig. 2. I-V curve with MPPT.

3.2. SCANNING OF PV MODULE WITH SHADOWING

In this case, 40 Wp module is partially shadowed: 4 cells on a total of 72.

4. I-V SCANNING WITH VOLTAGE REGULATION

4.1. SCANNING OF PV MODULE WITHOUT SHADOWING

An output voltage regulation is implemented in 40 Wp module converter as 50 Wp module is periodically scanned.

4.2. SCANNING OF PV MODULE WITH SHADOWING

The same configuration than 3.2.

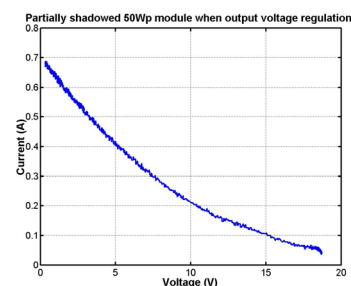


Fig. 3. I-V curve with output voltage regulation.

Supercapacitor characterization using fluctuating DC-current for Micro-grids applications based on Wind and Tidal energies generation systems

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Abstract - This paper presents the supercapacitor parameters variations due to impacts of the DC-current frequency in ambient temperature tests conditions. The goal of this study consists to show the parameters evolution which can serve to determine the lifetime of supercapacitor for different conditions of use. The contribution of the paper is focused on the DC-current frequency impacts characterization for supercapacitor resistance and capacitance. The proposed method uses several DC-current profiles based on fluctuations and no fluctuations consideration. To do the supercapacitors characterization, the experimental tests based on charge and discharge operations with dynamic (fluctuating) DC-current are done. The experimental tests results are presented and analysed.

Keywords – Characterization of supercapacitor, dynamic DC-current, state of charge, number of cycles, frequency impact, series resistance variation, capacitance variation.

1. INTRODUCTION

The supercapacitors are reversible electrochemical energy storage devices. They are well known for their good power performance and their very high life expectancy over batteries. They can be interfaced with others sources, through power electronics in many applications such as the decentralised generations systems and the transport ones. The contribution of this paper is focused on the impacts of the DC-current frequency characterization for supercapacitor series resistance and capacitance. The originality of this work compared to the literature information is based on DC-current frequency impact evaluation on the supercapacitors resistance and capacitance during the charging and discharge operations. To evaluate the proposed idea, the BOOSTCAP3000F/2.7V supercapacitor cell with a rated capacity of 3000 F is tested, [1]-[2]. The supercapacitor cell is charged and discharged with the dynamic DC-current through a bidirectional multi-channel converter as illustrated in Fig. 1.

2. SUPERCAPACITORS CHARACTERIZATION METHOD

The supercapacitor characterization based on fluctuating DC-current, requires using high sensitive measurement devices because the voltage and the impedance of the cell are low. To obtain a good performance in terms of voltage and current measurements, a good contact between the cell terminals and electrical wiring is necessary. In addition, the lengths of the electric wiring must be reasonable. The principle consists to impose the current profile through the test bench to charge and discharge the supercapacitor cell. The measured current and that of the voltage are saved in computer during real time operations through a data acquisition unit. The measured voltage and DC-current in real time operations are used to estimate the supercapacitor cell series resistance (*ESR*) and capacitance (*C*). These

parameters are calculated using the cell voltage experimental data corresponding to charge or discharge operations as illustrated in Fig.2.

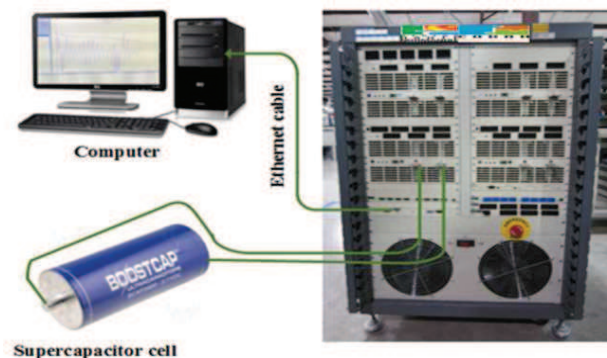


Fig.1. Supercapacitors characterization test bench.

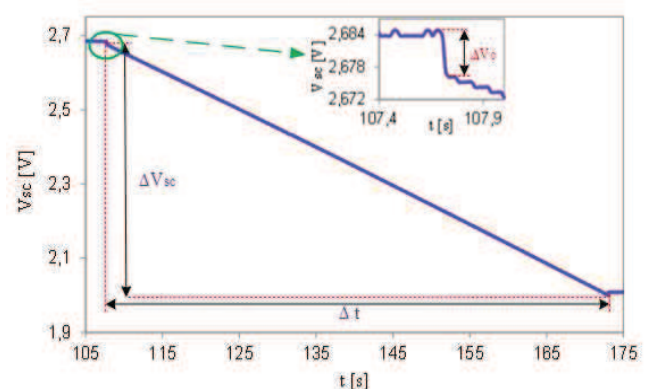


Fig.2. Supercapacitor cell discharge voltage.

The used methods for series resistance and cell capacitance estimation are respectively expressed by equation (1) and equation (2).

$$ESR = \frac{\Delta V_o}{I_{sc}} \quad (1)$$

$$C \approx \frac{\Delta V_{sc}}{\Delta t} \quad (2)$$

3. IMPACTS ON THE FREQUENCY ON CELL RESISTANCE AND CAPACITANCE

The frequency impact estimation is based on the supercapacitor charge and discharge using fluctuating DC-current as illustrated in Fig.3. The fluctuating DC-current profile is used for supercapacitor charge/discharge operations for several frequencies as illustrated in Fig.4. To characterize the supercapacitor resistance and capacitance evolutions, the tests procedure consists to stop the supercapacitor charge/discharge operations at 1000 cycles for each frequency presented in Fig.4 to estimate the resistance and capacitance using experimental data (supercapacitor voltage and current) and equations (1) and (2).

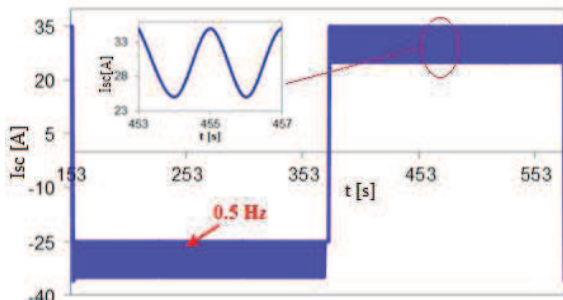


Fig.3. Fluctuating DC-current profile with frequency of 0.5Hz.

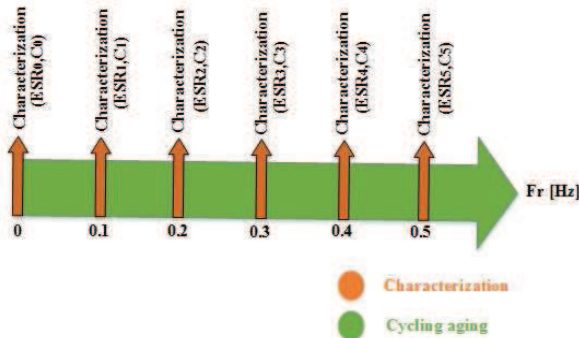


Fig.4. Supercapacitor experimental tests protocol according to the frequency F_r for each 1000 cycles.

This approach takes into account the variations of the supercapacitor resistance and the capacitance according to the frequency which can impact the supercapacitor life time. The resistance and capacitance are estimated at each 1000 cycles for each frequency that varies between 0 to 0.5Hz using described method in section 2. To show the frequency impacts on resistance and capacitance without that of the number of cycle, the estimated resistance and capacitance are divided by the previous values as expressed in following: $ESR(F_i)/ESR(F_{i-1})$ and $C(F_i)/C(F_{i-1})$, where $i=\{0,1,2,3,4,5\}$. After several thousand cycles of a same supercapacitor cell with a variable frequency, we note that there is a great difference between the first test result and last ones as presented in Fig.5. In other word the series resistance ESR is approximately constant between 0.1 and 0.3 Hz. This resistance increases quickly outer this interval and it reach about 20% compared to initial value of 0.221[mΩ]. Contrary to ESR , the cell capacitance decreases [3] with frequency increasing as presented in Fig.6, and it reach about 3%

compared to initial value of 3103 [F]. These two figures show that the resistance increases in a way important for high frequency DC-current compared to that of the low frequency, and conversely for the supercapacitor capacitance, which enables to conclude that, the DC-current profile has a direct impact on the resistance and capacitance of supercapacitor.

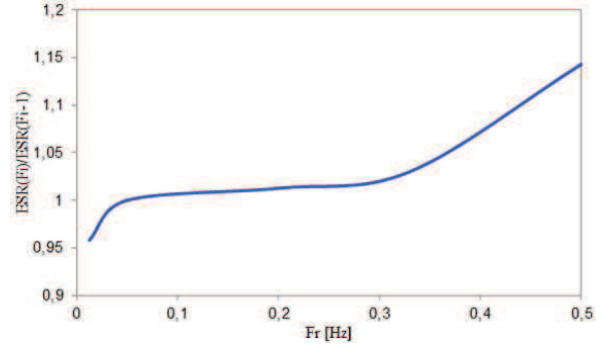


Fig.5. ESR variation according to the DC-current frequency.

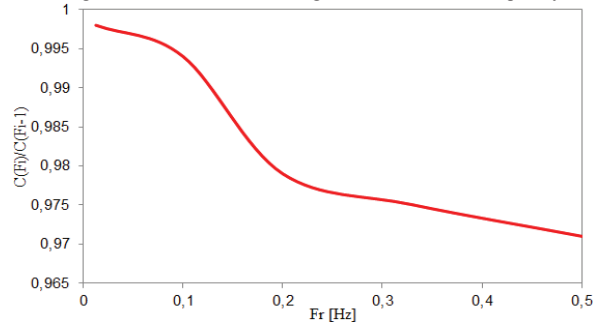


Fig.6: Supercapacitor capacitance variation according to the DC-current frequency.

4. CONCLUSION

In this paper the impacts of the DC-current frequency with state of charge is evaluated. The obtained results show that the supercapacitor cell capacitance and series resistance can be affected by the DC-current profile in more to impacts of the number of cycles and the state of charge. The experimental results show that the energetic performance of the supercapacitor decreases according to the cited physical characteristics. Finally, the supercapacitor cell test at ambient temperature with fluctuating DC-current shows that, the capacitance decreases and the series resistance increases according to the frequency.

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DECENTRALIZED MICROGRID COORDINATION USING MULTI-AGENT SYSTEMS

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Abstract - Microgrid (MG) networks are expected to help increase grid flexibility and the integration of renewable generation. To improve network cooperation performance, this paper proposes a novel distributed control strategy to manage energy flows using a multi-agent system. Power dispatching is achieved through flexible electricity markets to maximize MG profit. A distributed power flow calculation algorithm is proposed to guarantee that the power flow in the network is within line capacity. Simulation shows that the control strategy manages to ensure MG power balance while maximizing profit. Additionally, the power flow is within line capacity to guarantee system security.

Keywords – micro grid, multi-agent system, power management, distributed system, optimization

1. INTRODUCTION

For their operators, MGs are expected to help supply loads reliably and facilitate efficient renewable generation integration. However, as in current power systems, coordination among MGs could provide addition stability benefits, that individual MGs could not achieve. In this paper, two aspects of coordination are considered. The first is power dispatching, i.e., how MGs can trade power with each other. Then, results feasibility must be checked for line capacity violations.

2. CONTROL STRATEGY

2.1. POWER DISPATCHING

Events such as failures and faults can cause power imbalance in MGs. To reduce load shedding and generation curtailment, neighboring MGs can assist each other to compensate imbalances, while maximizing participators profit. Here, each agent controls an MG, monitors its facilities and negotiates with neighbor agents. An MG with insufficient generation is called a requester, and establishes an electricity market [1] to obtain the neighbours' power price and volume and divide the demand among them. A priority order is used, e.g., more power is taken from cheaper MGs.

2.2. POWER FLOW CALCULATION

As power supplied by one MG to others changes, power flows in the network change. However, line flow capacities (lines interconnecting MGs only) limit power transfers, the security of the network should be checked during the trading. Here, a distributed algorithm is run to obtain the connecting lines flow, as in equations (1)–(3) [2].

$$\Delta p_{n-1,s} = p_{n-1,s} - v_{n-1} \sum_{j \in (n-1)} v_j (g_{n-1,j} \cos \theta_{n-1,j} + b_{n-1,j} \sin \theta_{n-1,j}) = 0 \quad (1)$$

$$\Delta p_{n-1,s} = p_{n-1,s} - \sum_{j \in (n-1)} (g_{n-1,j} + b_{n-1,j} \theta_{n-1,j}) \quad (2)$$

where θ is the MG voltage angle. (1) is the power flow iteration equation. $p_{n-1,s}$ is the output power of MGs at the $(n-1)th$ iteration step. The second item in (1) is the sum of power flowing on the connecting lines. v is the voltage magnitude. $g_{n-1,j}$ and $b_{n-1,j}$ are the line conductance and susceptance between MGs $(n-1)$ and j . $\Delta p_{n-1,s}$ is the error value for the θ th iteration. This paper assumes that the voltage magnitude is 1 as only the active power is discussed. Assuming angles are small, $\cos \theta \approx 1$, $\sin \theta \approx \theta$. Substituting into (1), the power flow calculation becomes (2). Finally, in (3), a is an iteration parameter to correct the voltage angle:

$$\theta_{n,s} = \theta_{n-1,s} + a \times \Delta p_{n-1,s} \quad (3)$$

2.3. RESULTS

The simulated system contains 13 MGs. Results show that during the fault period at 54 min, the average load shedding is 204.79 W without coordination. With coordination, the load shedding is cancelled and the total electricity trading cost is 79.44€. Comparing power flows on the line between MGs 3 and 2, there is a 3.7% average error. Overall, results show that the reliability and efficiency of operation of the system is improved.

CONCLUSION

This work shows that through coordination, networked MGs can mutually benefit from assisting each other in case of difficulty.

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STORAGE MANAGEMENT OF GRID CONNECTED PV PRODUCTIONS FOR EFFICIENT SELF-CONSUMPTION IN BUILDINGS

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Abstract - While the development of a real-time, proactive, and smart grid promises to solve energy problems in the long term, consumers and businesses need effective and affordable solutions today for managing their energy consumption and costs. Intelligent energy management technologies can provide these immediate solutions. This paper describes a method of storage management of grid connected PV productions for efficient self-consumption in buildings. It introduces the concept of Multifunctional converter that ensures the power flux in the Hybrid Renewable Energy Systems (HRES) with its functionalities, the power management strategies and some sizing parameters. Results of experimental tests are presented and analyzed.

Keywords – Hybrid renewable energy system, PV, Energy management, Energy storage, Buildings.

1. INTRODUCTION

Hybrid Renewable Energy Systems (HRES) are becoming popular as stand-alone power systems for providing electricity in, grid-connected or not, systems due to advances in renewable energy productions and storage technologies in context of important rise in prices of petroleum products.

1.1. HRES ARCHITECTURE

A reference diagram for on-grid HRES, is presented in Fig. 1. The system is connected to the National Grid and integrates a 3kWc PV panels, a 5kWh Lithium-ion batteries, and a Multifunctional converter that ensure the power flow from sources to loads.

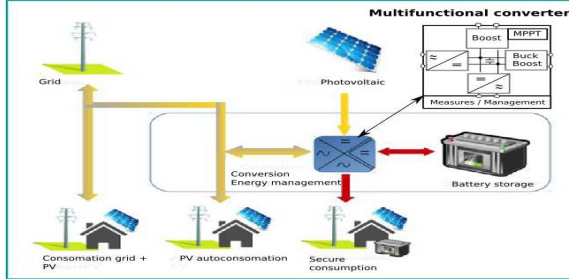


Fig.1. Hybrid renewable energy system

1.2. POWER MANAGEMENT STRATEGIES

The unpredictable nature of renewable resources leads to a very complex power management strategy. This can induce different situations in operation that are considered to propose scenarios of Fig.2.

1.3. SIZING OF THE SYSTEM COMPONENTS

A particle swarm optimization method (PSO) is used for system components design. The algorithm is takes into account the constraints of the real conditions of operation, so the cost function is defined in aims to minimize the Cost of electricity (COE) (1), according to the Net Present Cost (NPC, €) and the Net Present Value (NPV). This last is the present value of the investment for the considered time period 'n' related to the stated annual interest rate 'r'.

$$\begin{cases} COE(\frac{\$}{kWh}) = \frac{NPC(\$)}{NPV * \sum_{h=1}^{8760} P_{load}(h)(kWh)} \\ NPV = \frac{(1+r)^n - 1}{r(1+r)^n} \end{cases} \quad (1)$$

In HRES, it is important to improve the Renewable Energy Penetration Factor (REFact), defined as the ratio of the conventional to the renewable power (2).

$$REFact(\%) = \left(1 - \frac{P_{grid}}{P_{pv}}\right) * 100 \quad (2)$$

2. RESULTS OF EXPERIMENTAL TESTS

Experimental tests of the HRES were conducted during one day by using the PV and the Load reference profiles presented in Fig.2. The energy management strategy is based on the Priority rules of the self-consumption and of the electricity selling during the period of peak hour.

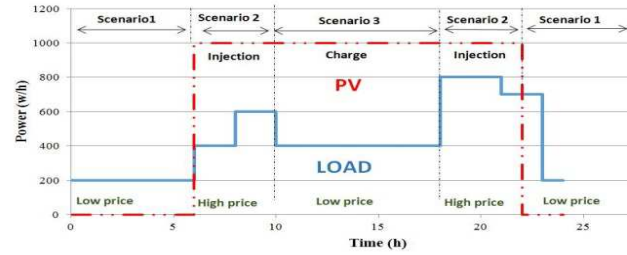


Fig.2. Profiles of load (blue) and production PV (red)

Results of the experimental tests are presented in Fig.3. It can be observed that the reference profiles are well followed by the controller and the supervision system.

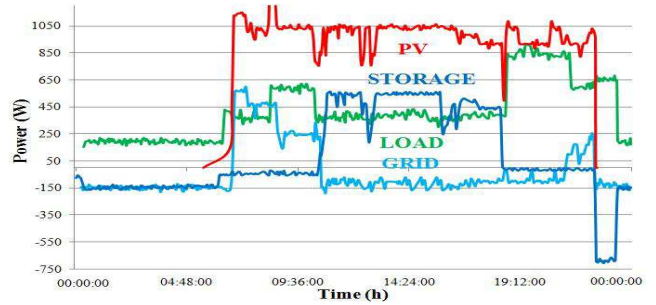


Fig.3. Powers exchanged between Load, Grid, PV and Lithium-ion batteries.

3. CONCLUSION

The total Power balance shows that energy management is efficient and ensure full self-consumption, through batteries charging and discharging process, with the possibility to inject the over production to the grid. Properly implemented, intelligent energy management help to cut energy use, spending, and emissions, and help to build tomorrow's smarter energy infrastructure.

In future work, it is planned to develop decision laws that can help prosumers to participate to the energy market, with possibility to exchange energy, from and to the grid, related to the electricity price time.

ADVANCED PASSIVITY-BASED CONTROL FOR A FUEL CELL/SUPER-CAPACITOR HYBRID POWER SYSTEM

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Abstract - An advanced passivity-based control is proposed to solve the converters coordination problem of a fuel cell/super-capacitor hybrid power system. Interconnection and Damping Assignment Passivity Based Control (IDA-PBC) is applied to design the controller. This nonlinear controller considers the state-of-charge of the super-capacitor and achieves the stability of the whole closed-loop system. Its feasibility for an electrical vehicle is proven by simulation results and a comparison with an earlier method.

Keywords – Energy Management, Fuel Cell, IDA-PBC, Passivity Based Control, Super-capacitors.

1. INTRODUCTION

Interconnection and Damping Assignment–Passivity Based Control (IDA-PBC) is applied in a fuel cell/super-capacitor hybrid power system. This nonlinear controller uses matrices that are related to the interconnection between the subsystems and the damping of the system to find a desired command that achieves the stability of the whole closed-loop system. M. Hilaiet et al. [1] applied IDA-PBC for a regular two-converter parallel system with a fuel cell (FC) and supercapacitors (SCs). In their research, some terms of the general control were set to zero in order to obtain regular control strategies.

The novelty of this work is to exploit all the terms of the general non-linear control in order to integrate some components constraints directly in the control, while preserving the stability of the whole closed-loop system.

2. ADVANCED POWER MANAGEMENT STRATEGY

A two-converter parallel structure is used for the fuel cell/super-capacitors system shown in Fig. 1.

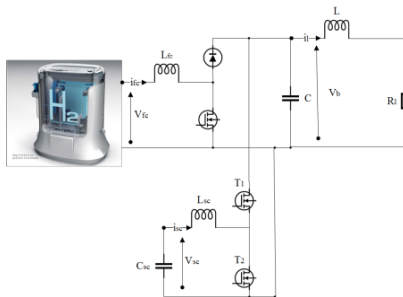


Fig. 1: System model

The main idea of the energy management strategy is to use the FC to supply the load and use the SCs during transients in order to stabilize the DC bus, with a proof of the stability of the whole closed-loop system.

Based on the previous strategy described in [1], a saturation of the SCs current is added to consider the

state-of-charge of SCs by integrating a variable r_2 . The control law is as follows:

$$i_{sc}^{**} = i_{sc}^* + r_2 C_{sc}^2 \tilde{v}_{sc} \quad (1)$$

$$i_{fc}^{**} = i_{fc}^* - r_2 \frac{v_{sc}}{v_{fc}} C_{sc}^2 \tilde{v}_{sc} \quad (2)$$

where i_{sc}^* , i_{fc}^* are control inputs obtained in [1], and \tilde{v}_{sc} is the error between the voltage of super-capacitors and its equilibrium point.

3. SIMULATION RESULTS

Fig. 2 shows a comparison between the original control (in blue) proposed in [1] and the new one (in red). Here, the voltage of SCs is limited between 20.5 V and 21.5 V for the purpose of the test. It follows that the SCs current goes to 0 when the voltage exceeds the limitation around 20 and 30s. In order to counteract the injection of current in the DC bus, the FC current is naturally increased, and consequently preserves the stability of the whole closed-loop system.

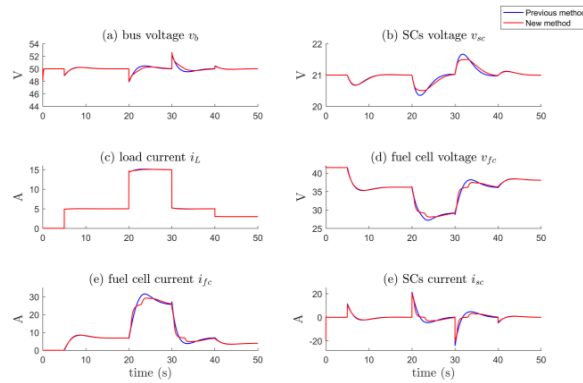


Fig. 2: Simulation results

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POWER LINE COMMUNICATION FOR BATTERY MANAGEMENT SYSTEM IN AN AUTONOMOUS PHOTOVOLTAIC LED LIGHTING SYSTEM

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Abstract – In an autonomous photovoltaic system, energy management is highly important. The batteries is used in the system to store the energy. It needs to be equipped with a battery management system (BMS) for power flow control, lifetime improvement and safety issues. In order to avoid the use of additional wire for communicating which will cause cost increasing, the power line communication is employed to manage power in the system.

Keywords – Power line communication, Battery management system, Photovoltaic, LED lighting system.

1. INTRODUCTION

The combinations of LED technology and photovoltaic technology makes up a new step in light technology. LED lighting system is suitable to employ in remote area without any help from AC grid. Thus, the battery management system need to ensure enough energy to support for the system in a long duration without the sun [1]. The proposed solution allows exchanging information between LED poles on the DC power bus.

2. SYSTEM OVERVIEW

2.1. POWER LINE COMMUNICATION SCHEMATIC

The schema for battery management system is shown in Fig.1. The battery will connect with the converter through 3 ports. Two ports will connect with 2 nearby LED poles. The PLC module will connect with main controller to get data as well as send command to control the power flow.

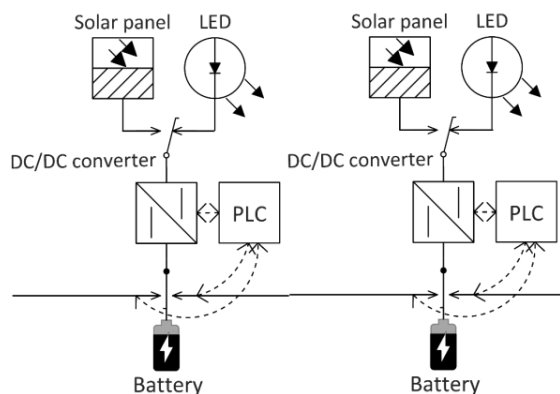


Fig. 1. Schematic for battery management system

2.2. CONTROL STRATEGY

In the daytime, the irradiance is different in different areas, the abstracted power from each PV is different one battery will be full sooner than the others will. Thus, transferring power will help to decrease charging time and power loss in the system. The same in the night case, when one battery runs out of energy before the others because each battery does not have the same age as well

as the same characteristic. The LED can be powered by the battery from the other LED pole. The BMS will send/receive order and data to local LED pole, communicate with other LED poles to know their state and supply power for the others if necessary.

2.3. EXPERIMENTAL RESULTS

In this system, narrowband PLC is used. Some communication tests in CENELEC A band (35kHz – 91kHz) and FCC (151.367kHz – 471.68kHz) have been made using PLC coupling module from Microchip. The Physical and Medium Access Control Layer of this module works on PLC G3 [2]. The system can change the mode (day/night) based on the signal from master pole, send/receive data (voltage, current) and show in the supervision.

2.4. CONCLUSION

This paper presents a BMS solution based on PLC technology. This solution is designed to take advantage of an existing wire infrastructure. It has been developed for an off-grid LED system in order to communicate over the DC power bus to energy safety in the system.

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PREDICTIVE CURRENT CONTROL IN GRID CONNECTED PHOTOVOLTAIC SYSTEM

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Topic: Power quality for microgrids **Preference for:** dialogue

Abstract - This paper proposes a predictive current control in multifunctional grid-connected photovoltaic system. To ensure the multifunctional feature, the proposed control uses the system discrete-time model to predict the future value of the inverter current. The selection of the optimal voltage vector aims to minimize the error between reference and predicted current, using a cost function. Then, Perturb and Observe Maximum Power Point tracking algorithm is applied to the dc-dc boost converter for extracting maximum power from the photovoltaic array. Simulation and experimental results confirm the effectiveness of the proposed control method in terms of total harmonic distortion and power factor correction.

Keywords – Predictive current control, Power quality, Photovoltaic system, harmonics.

2

1. INTRODUCTION

Various control strategies have been proposed for the control of grid connected photovoltaic systems. Among them, hysteresis and linear control with pulse width modulation are the most cited in the literature [1]. Nevertheless, with the development of micro-controllers and digital signal processors with high computational capabilities, implementation of more complex and intelligent control schemes is possible. One of these intelligent algorithms is Model Predictive Control (MPC), which is an attractive alternative to classical control techniques [1], [2].

This paper presents a multifunctional grid-connected two-level three-wire inverter, interfaced with a PV system and the basic working principles of a predictive current control scheme. Simulation and experimental results are carried out under a Matlab/SimulinkTM environment in order to validate the robustness of the proposed method.

2. SYSTEM CONFIGURATION

The suggested multifunctional system is presented in the following figure (Fig. 1).

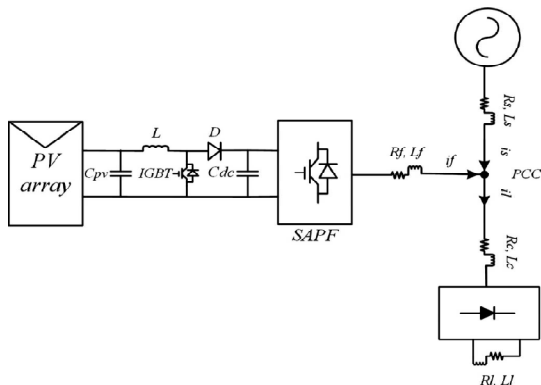


Fig. 1. Multifunctional photovoltaic system configuration.

2.1. EXPERIMENTAL RESULTS

Figure 2 depicts the experimental results of the proposed algorithm in the power generation mode. The source current is compensated with a unity power factor shown in its lower THD and power factor values.

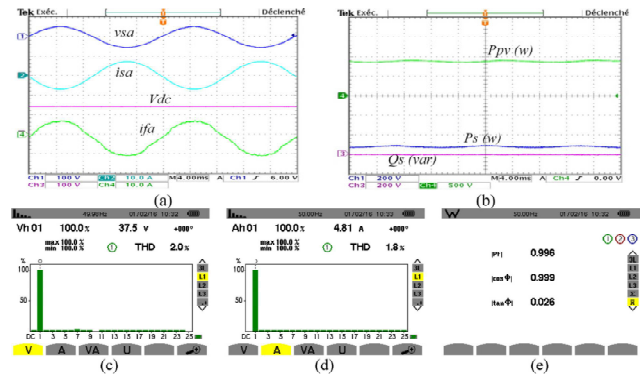


Fig. 2. Experimental results of the proposed PV system.

3. CONCLUSION

This paper has proposed a predictive current control algorithm for a multifunctional grid connected inverter interfaced with a PV-system. The control strategy suggested uses a discrete-time model for the shunt active power filter to predict the behavior of the filter current as well as to minimize the error between the estimated and predicted current by means of the quality function.

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OPTIMAL ENERGY MANAGEMENT OF MULTISOURCE PRODUCTION SYSTEM FOR SELF-CONSUMPTION IN ISOLATED AREAS

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Abstract—In this paper, a new energy management strategy (EMS) is designed for a hybrid power system composed of photovoltaic panels (PV) and Proton Exchange Membrane Fuel Cell (PEMFC) as energy sources, a battery and ultracapacitor (UC) as energy storage systems (ESS). The designed EMS is based on residential power and solar power forecasting. The main aim of the proposed strategy is to reduce the total operating cost of the system while satisfying the constraints required by the ESS.

Keywords – Hybrid power system; energy management strategy; operating cost.

1. INTRODUCTION

Thanks to their benefits related to environment and transmission losses, hybrid power systems based on renewable energies represent one of the possible solutions to supply applications located in isolated areas. The general architecture of these systems can include Renewable Energy Sources (RES), generators (for example Diesel generator and fuel cell) and also Energy Storage Systems [1], [2]. An Energy Management System is then always required to control the system's elements in a way that optimizes a predefined objective. This work deals to an energy management solution for a multisources power system which supply a residential load. The proposed EMS is based on Centred Moving Average filters which are well suited to consider both futur (predictions) and past (measures) data. An optimization process is proposed to define the best filtering horizon, considering an objective of cost minimization.

2. MICROGRID STRUCTURE AND EMS

The scheme of the studied hybrid system is shown in fig.1. It includes PV panels as a main energy source, a fuel cell as secondary energy source, a battery array and UC as ESS. An optimal power sharing between these four subsystems is ensured by the EMS, while respecting their dynamics, the storage limits of the ESS and minimizing the total operating cost of the system.

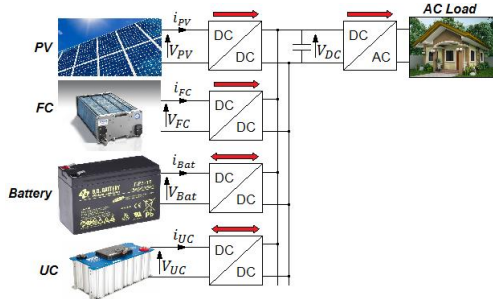


Fig. 1. Schematic diagram for the Hybrid Power System

The proposed strategy is shown in fig.2. Based on two Centred Moving Average (CMA) filters [3], it generates reference powers for the FC and the battery. The power generated by the PV panels is totally used.

The UC is responsible for generating the necessary residue which satisfy the load demand. These different elements are differentiated by their dynamics. Indeed, the PEMFC has the slowest dynamic while the UC is the fastest subsystem. In order to generate reference powers which respect the dynamics of the PEMFC and the battery, the two filtering horizons of the two filters, named $Scale_1$ and $Scale_2$ must have a well-defined order. On the other hand, these two variables represent the optimization variables to be sought in order to minimize the total operating cost of the system. For this purpose, the reference powers of the PEMFC and the battery are expressed as a function of the two filtering horizons. The objective function is defined as the cost of Hydrogen consumption and the cost of the aging of the battery. It is written as a function of the scales 1 and 2. Particular Swarm Optimization algorithm is used to find their optimal values that minimize the objective function.

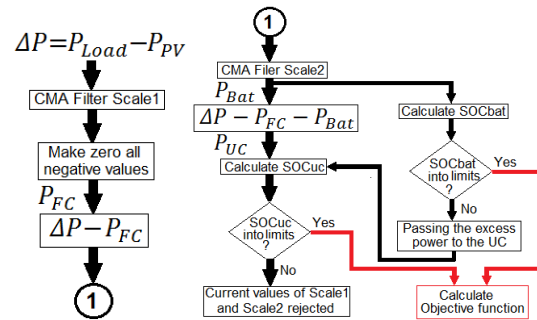


Fig. 2.Design of the EMS

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Microgrid and Electromobility for Urban Areas

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Abstract—Greenhouse gas emissions, produced by transport sector, have spurred the rapid growth of the electromobility. Nevertheless, this new form of mobility requires installing recharging infrastructures for electric vehicles (EVs) in urban areas, both self-service and not. This paper aims at: a) presenting an innovative energy system, and b) at highlighting the issues for its implementation in an urban area. The proposed energy system consists of three components: an intelligent charging station for electric vehicles (iCS_EVs), a heterogeneous fleet of electric vehicles (EVs), and a building with a connection to the iCS_EVs. This paper focuses on requirements and feasibility of iCS_EVs best fitting urban areas. This energy system is embedded into the urban space in which is installed through multiple physical and logical interactions. The iCS_EVs is based on a smart microgrid optimizing the power flows in accordance with the requirements of the public power grid. This microgrid contains photovoltaic sources and takes into account the following strategies: vehicle to grid, vehicle to building, and iCS_EVs to building (energy generated by the iCS_EVs and not used by the EVs directly feeds the building). Therefore, the innovative energy system offers new services that can be synergistic with the urban electromobility.

Keywords— *electromobility; microgrid; renewable energy; electric vehicles; urban planning.*

I. INTRODUCTION

Electric vehicles (EVs) represent an important step towards the transition to low-carbon urban mobility [1]. Nevertheless, recharging EVs increases the energy consumption in real time. Due to the high current required, and depending on when and where the EVs are connected, the charging stations cause problems and constraints for the power grid [2]. The indirect pollution created by charging stations depends on the energy mix of electricity production allowing peak consumption, *i.e.* the spinning reserve composed mainly of fossil fuel-based power plants. In order to respond to EVs recharging, this spinning reserve should be expanded. Moreover, with regard to users, their preference to recharge the EVs is usually at the appropriate time rather than out of peak periods [3]. Thus, starting from a certain total power demand, representing the recharge of EVs during the day period, the power grid could be strongly affected [4]. This paper aims at presenting an innovative energy system, which proposes new services associated with the urban electromobility, highlighting the issues for its implementation in an urban space.

II. INTELLIGENT CHARGING STATION FOR ELECTRIC VEHICLES

The innovative energy system is defined as a set of objects, an intelligent charging station for electric vehicles (iCS_EVs), a heterogeneous fleet of EVs, and a building having a connection to the iCS_EVs. The goal is to provide iCS_EVs in urban areas while facilitating interactions between iCS_EVs, the power grid, surrounding building and users of EVs and building. EV is defined as a vehicle whose propulsion is ensured exclusively by one or more electric motors. The iCS_EVs

is based on a smart microgrid [2] that optimizes the power flows in accordance with the requirements of the public power grid [5]. This microgrid contains PV sources, electrochemical storage, supercapacitors, and connection to the public grid.

One of the solutions can be the microgrid integrated in the car parking where PV panels are installed on sun-shading roofs as shown in Fig. 1. This energy system is able to manage optimized power flows and takes into account the following strategies: Vehicle to Grid (V2G), discharge of EVs batteries into the public grid; Vehicle to Building (V2B), discharge of EVs batteries into building; iCS_EVs to Building (i2B), electrical supply of building by iCS_EVs.

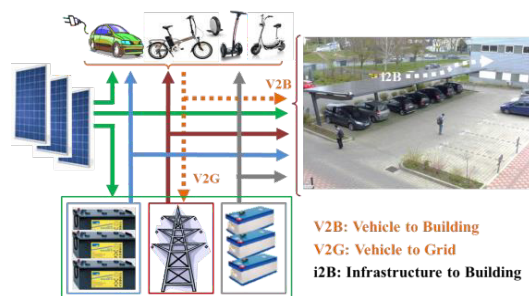


Figure 1. iCS_EVs of Université de Technologie de Compiègne.

The V2G strategy allows the peaks of consumption to be smoothed at the power grid level, while V2B leads to the securing of the building supply during an electrical cut-off. The i2B strategy means that energy generated by the iCS_EVs and not used by the EVs directly feeds the building. Currently, there is a lack of maturity for these

strategies. The literature mainly focuses on the topology of the bidirectional interface and its control when switching to V2G or V2B mode. For the V2G mode there are specific studies in Germany, Spain, Denmark, and Brazil. Regarding France, there is no applied research concerning V2G/V2B modes. Concerning the communication between the EVs and the charging station, some studies analyze the security modes to protect the users' data; other studies are interested in the methods of identification of the EVs connected to the terminals, or in the performance of the wireless connection for the V2G mode.

Nowadays PV integrated car parking shades exist, but inject the total produced energy into the public grid and the V2G mode is used to compensate for the intermittent nature of PV energy. The control algorithms are not optimized and only take into account the state of charge of the EVs batteries. Moreover, there is not a technical-economic optimization algorithm; constraints related to the use of the power grid are not taken into account and interfacing with the end-user is not provided. However, several works deal with the possibility of using the V2G mode to participate in ancillary services. Often, within the limit of the possible discharge threshold, EV is seen as a conventional energy reservoir for setting the frequency. Some publications are focused on the generation of reactive power; furthermore, the use of EVs connected to charging stations is related to the whole city or larger areas and less often to a specific urban neighbourhood or defined local urban area. The main objective of planning the EVs' use on large areas is to improve the energy efficiency and safety in the power grid. Thus, scenarios, taking into account a varying number of EVs using the V2G mode, with different constraints, are simulated and allow a statistical analysis.

To sum up, several aspects concerning the V2G and V2B strategies are already well developed. However, in the absence of a proposal of a smart microgrid dedicated to the EVs recharging, the i2B strategy is not proposed. Furthermore, the systemic aspect of such an innovative energy system, implanted in an urban space and defined as a set of objects, *i.e.* iCS_EVs, EVs and a nearby building, or the interaction of the system with end-users and its environment is not currently in the literature. Therefore, new services at the urban level are not proposed. Moreover, most of the concepts and tools are validated through simulation and not thanks to experimentation.

The AVENUES laboratory of Université de Technologie de Compiègne (UTC) built a technological platform called STELLA, Smart Transport and Energy Living Lab. STELLA is a microgrid demonstrator dedicated to EVs recharging and powering a building. This demonstrator, shown in Fig. 2, is based on PV panels (28.9 kW nominal) covering 9 parking spots of the UTC Innovation Center, electrochemical storage, supercapacitors, power electronics, power grid and building connections.



Figure 2. Technological platform STELLA.

This platform, funded by the European Union (FEDER fund) under the CPER grant, is operational since 2016 and unique in France at the academic level. More details on the technological platform will be provided in the final paper.

III. CONCLUSION

The proposed iCS_EVs and the associated services represent an incremental innovation in relation to a range of existing PV integrated car parking shade, which produces clean energy, but in passive mode without ancillary services, rarely consumed locally, or rarely in interaction with the end-users

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Efficient energy management for an elevator system under a constrained optimization framework

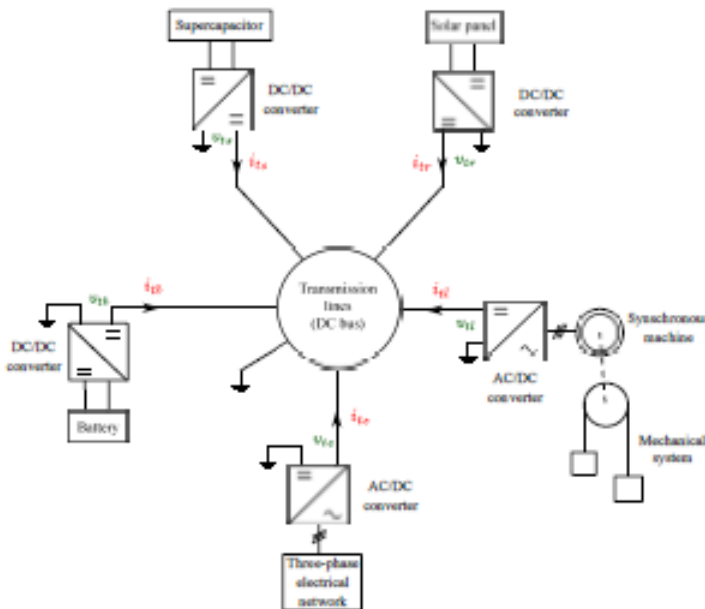
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Abstract: This work considers a constrained optimal control for the load in a DC microgrid elevator system (see Figure 1 and Paire (2010)). The mentioned microgrid includes batteries, supercapacitors, solar panels and a load system. The latter is composed by a mechanical elevator and a Permanent Magnet Synchronous Machine (PMSM). All these microgrid components are connected together through the DC bus and associated converters. The microgrid system is connected to the three phase electrical grid through a DC/AC converter.

Having as global objective the minimization of the purchasing/selling electricity cost within the microgrid (Pham et al. (2017)), we concentrate here on the dissipated energy minimization while respecting constraints for the load and the associated AC/DC converter. By assuming that the dissipation on the mechanical elevator and on the converter is negligible, only the dissipation on the machine is taken into account. The considered constraints include the limits on the currents, voltages, machine speed and elevator position.

A well-known method which deals with the constraints and cost is Model Predictive Control (MPC) (Rawlings and Mayne (2009)). However, using MPC with a long prediction horizon requires a high computation capacity which is not always available. Thus, we choose here to address the off-line reference profile generation and the on-line tracking control. In this work, we use differential flatness (Lévine (2009)) and B-spline-based parametrization (Suryawan (2011)) for respecting the system dynamics and state and input constraints. On-line we employ through the use of MPC the optimal reference profile tracking. The results are validated in simulation under different scenarios.



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Fig. 1. The DC-microgrid elevator system.

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